AEDC-TSR-79-V71
c.X

BOUNDARY LAYER MEASUREMENTS ON SLENDER BLUNT CONES AT FREE-STREAM MACH NUMBER 8

L. G. Siler and J. C. Donaldson
ARO, Inc.

December 1979

Final Report for Period 21 September 1979 - 25 September 1979

ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENNESSEE
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

APPROVAL STATEMENT

This report has been reviewed and approved.

Joseph F. Pawlick

JOSEPH F. PAWLICK, Jr., Lt. Col, USAF
Test Director, VKF Division
Directorate of Test Operations

Approved for publication:

FOR THE COMMANDER

John C. Hartney

JOHN C. HARTNEY, Colonel, USAF
Director of Test Operations
Deputy for Operations

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AEDC-TSR-79-V71

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Boundary Layer Measurements on Slender Blunt Cones at Free-Stream Mach Number 8

5. TYPE OF REPORT & PERIOD COVERED
Final Report - September 21 to 25, 1979

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
L. G. Siler, and J. C. Donaldson, ARO, Inc., a Sverdrup Corporation Company

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Arnold Engineering Development Center/DO
Air Force Systems Command
Arnold Air Force Station, Tennessee 37389

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Program Element 61102F

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Flight Dynamics Laboratory/FXG
Wright-Patterson Air Force Base, Ohio 45433

12. REPORT DATE
December 1979

13. NUMBER OF PAGES
56

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available in Defense Technical Information Center (DTIC).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
hypersonic flow
blunt bodies
wind tunnel tests
laminar boundary layer surveys
adiabatic-wall tests
hot-wire anemometer
boundary layer stability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Boundary layer profiles and surface conditions were measured on a slender cone with various nose bluntnesses with a laminar boundary layer and with the wall temperature in a state of equilibrium. The measurements were made at a free-stream Mach number of 8 for unit Reynolds numbers from 1.3 to 3.5 million per foot. Surveys were made using a hot-wire anemometer and total temperature and pressure probes. Descriptions of the test apparatus, procedures, and techniques used are given in this report.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

CONTENTS

APPENDIXES

Page

II. TABLES

Table

III. SAMPLE DATA

NOMENCLATURE

ALPHA, ALPHA-SECTOR, α	Angle of attack, deg
CONFIGURATION	Model configuration designation
C.R.	Center of rotation, tunnel centerline axial station about which model rotates in pitch, in.
CURRENT	Hot-wire heating current, ma
d	Thermocouple junction diamter, 0.005 in.
DATA TYPE	Code indicating nature of data tabulated:
	HEAT TRANSFER - Cold wall model surface heat-transfer measurements
	"2" - Model surface pressure measurements
	"3" - Qualitative hot-wire anemometer and total temperature probe boundary-layer profile measurements
	"4" - Mean boundary layer profile measurements using pitot pressure and total temperature probes
	"6" - Total temperature probe calibrations
	"9" - Quantitative hot-wire anemometer data at particular point locations within a survey
DEL, δ	Boundary-layer total thickness (where UL/UE = 0.995), in.
DEL*	Boundary-layer displacement thickness, in.
DEL**	Boundary-layer momentum thickness, in.
DEW PT	Frost point, °F

DITTD	Enthalpy difference at boundary-layer thickness, DEL, ITTD-ITWL, Btu/lbm
DITTL	Local enthalpy difference, ITTL-ITW, Btu/lbm
EBAR	Hot-wire mean voltage, mv
ERMS	Anemometer output rms voltage, mv
ETA	Effective total-temperature probe recovery factor
H(TT)	Heat transfer coefficient based on TT, QDOT/(TT-TW), Btu/ft^2-sec-^{o}R
ITT	Enthalpy based on stilling chamber total temperature, Btu/lbm
ITTD	Enthalpy based on TTD, Btu/lbm
ITTL	Enthalpy based on TTL, Btu/lbm
ITW	Enthalpy based on model wall temperature, Btu/lbm
ITWL	Enthalpy based on TWL, Btu/lbm
LRE	Local unit Reynolds number, in.$^{-1}$
LRED	Unit Reynolds number at the boundary-layer thickness, DEL, in.$^{-1}$
LRET	Local "normal shock" unit Reynolds number (based on MUTTL), in.$^{-1}$
LRETA	"Normal shock" unit Reynolds number at ZA (based on MUTTL), in.$^{-1}$
LRETD	"Normal shock" unit Reynolds number at boundary-layer thickness, DEL (based on MUTTD), in.$^{-1}$

M, MACH	Free-stream Mach number
MA	Local Mach number at ZA
MD	Local Mach number at boundary-layer thickness, DEL, $in.^{-1}$
ME	Mach number at boundary-layer edge
ML	Local Mach number
MODEL ROLL, ROLL	Roll angle, deg
MU	Dynamic viscosity based on T, $lbf\text{-}sec/ft^2$
MUTD	Dynamic viscosity based on TD, $lbf\text{-}sec/ft^2$
MUTL	Dynamic viscosity based on TL, $lbf\text{-}sec/ft^2$
MUTT	Dynamic viscosity based on TT, $lbf\text{-}sec/ft^2$
MUTTD	Dynamic viscosity based on TTD, $lbf\text{-}sec/ft^2$
MUTTL	Dynamic viscosity based on TTL, $lbf\text{-}sec/ft^2$
P	Free-stream static pressure, psia
PHI, ϕ	Roll angle, deg
PITCH	Angle of attack, deg
PP	Probe pitot pressure, psia
PPD	Pitot pressure at boundary-layer thickness, DEL, psia
PPE	Pitot pressure at boundary-layer edge, psia
PT	Tunnel stilling chamber pressure, psia
PT2	Free-stream total pressure downstream of a normal shock wave, psia

PW	Model surface pressure, psia
PWL	Model wall static pressure used for boundary-layer survey, psia
Q	Free-stream dynamic pressure, psia
QDOT	Heat transfer rate, Btu/ft^2-sec
RE,RE/IN.	Free-stream unit Reynolds number, in.$^{-1}$
RE/FT	Free-stream unit Reynolds number, ft^{-1}
RET	Free-stream "normal shock" unit Reynolds number (based on MUTT), in.$^{-1}$
RHO	Free-stream density, lbm/ft^3
RHOD	Density at boundary-layer thickness, DEL, lbm/ft^3
RHOL	Local density, lbm/ft^3
RHOUD	(RHOD) · (UD), lbm/sec-ft^2
RN, RADIUS	Model nose radius, in.
RUN	Data set identification number
S	Curvilinear surface distance from model stagnation point, in.
SD PW	Model wall pressure standard deviation
SD TW	Model wall temperature standard deviation
SREF	Model reference curvilinear surface distance (from stagnation point to base), in.
ST(TT),STINF	Stanton number based on stilling chamber temperature (TT), $ST(TT) = \frac{QDOT}{(RHO)(V)(ITT-ITW)}$

T	Free-stream static temperature, °R
TAP	Pressure orifice identification number
T/C	Thermocouple identification number
TD	Static temperature at boundary-layer thickness, DEL, °R
TDRK	Temperature of druck transducer, °F
THETA, θ	Peripheral angle on the model measured from ray on model top, positive clockwise when looking upstream, deg
TL	Local static temperature, °R
TRIP	Boundary-Layer trip identification
TT	Tunnel stilling chamber temperature, °R
TTA	Total temperature at ZA, °R
TTD	Total temperature at boundary-layer thickness, DEL, °R
TTE	Total temperature at boundary-layer edge, °R
TTL	Local total temperature, °R
TTLU	Uncorrected (measured) probe total temperature, interpolated at ZP, °R
TTTU	Uncorrected (measured) probe total temperature, °R
TW	Model surface temperature, °R
TWL	Model wall temperature used for boundary-layer survey, °R

UD	Local velocity component parallel to model surface at boundary-layer thickness, DEL, ft/sec
UE	Local velocity component parallel to model surface at boundary-layer edge, ft/sec
UL	Local velocity component parallel to model surface, ft/sec
V	Free-stream velocity, ft/sec
X	Axial location located from virtual apex of 7-deg cone model, in.
ZA	Anemometer-probe height, distance to probe sensor along normal to model surface, in.
ZP	Pitot-pressure probe height, distance to probe centerline along normal to model surface, in.
ZT	Total-temperature probe height, distance to probe centerline along normal to model surface, in.

1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 61102F, Control Number 2300-99-9, at the request of the Air Force Office of Scientific Research (AFOSR/NA), Bolling Air Force Base, Washington, D.C. for the Air Force Flight Dynamics Laboratory (AFFDL/FXG), Wright-Patterson Air Force Base, AFSC, Wright-Patterson Air Force Base, Ohio. The AFOSR/NA project monitor was Dr. James Wilson and the AFFDL/FXG project monitor was Mr. Kenneth Stetson. The results were obtained by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), operating contractor for the AEDC, AFSC, Arnold Air Force Station, Tennessee. The test was conducted in the von Kármán Gas Dynamics Facility (VKF), Tunnel B during the period September 21 through 25, 1979, under ARO Project No. V41B-B2.

The test objective was to experimentally identify the turbulence mechanism within a laminar boundary layer which promotes boundary-layer transition on a blunt body of revolution in a hypersonic stream. To accomplish this, flow field surveys were obtained at a free-stream Mach number of 8 using a probing system instrumented with a hot-wire anemometer, a total temperature probe, and a pitot pressure probe. The model configuration used was a 7-deg (half-angle) cone with four interchangeable nosetips of various bluntness (sharp, 3%, 10%, and 40% referenced to the base radius). Tests were conducted at a single free-stream unit Reynolds number for each bluntness configuration ranging from 1.0 to 3.5 x 10^6 per foot. All surveys were made at zero angle of attack at equilibrium wall temperatures (TW/TT of approximately 0.75). Model surface pressure, heat-transfer, and temperature distributions were also obtained.

Inquiries to obtain copies of the test data should be directed to AFFDL/FXG, Wright-Patterson Air Force Base, Ohio 45433. A microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel B (Fig. 1) is a closed circuit hypersonic wind tunnel with a 50-in.-diam test section. Two axisymmetric contoured nozzles are available to provide Mach numbers of 6 and 8 and the tunnel may be operated continuously over a range of pressure levels from 20 to 300 psia at Mach number 6, and 50 to 900 psia at Mach number 8, with air supplied by the VKF main compressor plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 1350°R) are obtained through the use of a natural gas fired combustion heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external

water jackets. The tunnel is equipped with a model injection system, which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel may be found in the Test Facilities Handbook, Ref. 1.

2.2 TEST ARTICLE

The basic model configuration was a 7-deg half-angle cone with a virtual length of 40 in. as shown in Fig. 2. Model nose bluntnesses of 0.150-in. (3% bluntness), 0.500-in. (10% bluntness), and 2.000-in. (40% bluntness) radius were tested in addition to the baseline sharp nose (RN = 0.0015 in.) configuration. Model components were fabricated from type 304 stainless steel at the AEDC.

The model was instrumented with pressure orifices and coaxial surface thermocouple gages. Table 1 (Appendix II) lists the instrumentation locations and indicates that the top centerline ($\theta = 0$) was the main ray of pressure instrumentation and the bottom centerline ($\theta = 180$ deg) was the only ray instrumented with thermocouple gages. Pressure orifices were also installed on the $\theta = 180$ and 270 deg rays at three additional axial stations.

A model installation photograph is presented in Fig. 3.

2.3 FLOW FIELD SURVEY MECHANISM

Surveys of the flow field were made using a retractable survey system (X-Z Survey Mechanism) designed and fabricated by the VKF. This mechanism makes it possible to change survey probes while the tunnel remains in operation. The mechanism is housed in an air lock immediately above a port in the top of the Tunnel B test section. Access to the test section is through a 40-in.-long by 4-in.-wide opening which can be sealed by a pneumatically-operated door when the mechanism is retracted. Separate drive motors are provided to (1) insert the mechanism into the test section or retract it into the housing, (2) position the mechanism at any desired axial station over a range of 35 in. and (3) survey a flow field of approximately 10-in. depth. The survey mechanisms were used in combination to traverse the probes across the flow field. A pneumatically-operated shield was provided to protect the probes during injection and retraction through the tunnel boundary layer, during changes in tunnel conditions, and at times when the probes were not in use.

2.4 FLOW FIELD PROBES

The pitot-pressure probe was made by flattening a 0.025-in. O.D. (0.020 I.D.) tube, as shown in Fig. 4a, which produced a probe tip thickness of 0.011 in. with an open slit height of 0.006 in. The tube section behind the orifice tube was bent in such a manner as to hold the probe alignment parallel to the model surface during the surveying sequence.

The hot-wire anemometer probes were fabricated by the VKF. Platinum-10% rhodium wires, drawn by the Wollaston process, of 20-μ in. nominal diameter and approximately 150 diameters length, were attached to sharpened 3-mil nickel wire supports using a bonding technique developed by Philco-Ford Corporation (Ref. 2). The wire supports were inserted in an alumina cylinder of 0.031-in. diam and 0.25-in. length, which was, in turn, cemented to an alumina cylinder of 0.094-in. diam and 3.0-in. length that carried the hot-wire leads through the probe holder of the survey mechanism.

The unshielded total temperature probe was fabricated by the VKF from a length of sheathed thermocouple wire (0.010-in. O.D.) with two 0.0015-in. diameter wires. The wires were bared for a length of about 0.015 in. and a thermocouple junction of approximately 0.007-in. diam was made. Details of this probe are shown in Fig. 4b.

A sketch of the survey probe rake used during the test is illustrated in Fig. 5.

2.5 TEST INSTRUMENTATION

2.5.1 Tunnel Conditions

The measuring devices, recording devices, and calibration methods for all measured parameters during this test, with the exception of the hot-wire anemometer instrumentation, are listed in Table 2 along with the estimated measurement uncertainties. The uncertainties in the stilling chamber properties, as itemized in this table, are used in conjunction with previously established nozzle Mach number calibrations as the basis for defining the uncertainties in the test section properties. Also identified in Table 2 are the standard wind tunnel instruments and measuring techniques used to define such test parameters as the model attitude, the model surface pressures, probe positions, and probe measurements. The following additional special instrumentation was also used in support of this test effort.

2.5.2 Model Surface Heat Transfer Measurements

Coaxial surface thermocouple gages were used to measure the model surface heating rates and surface temperatures. The coax gage consists of an electrically insulated Chromel® center enclosed in a cylindrical Constantan sleeve. After assembly and installation in the model, the gage materials are blended together with a file creating thermal and electrical contact in a thin layer at the surface of the gage. The gage is used to monitor the surface temperature time history at a rate of 15 points per second. Assuming the surface thermocouple behaves as a homogeneous, one-dimensional, semi-infinite solid, its temperature time history can be used to define the corresponding time history of the incident heat flux. A complete description of this gage and the data reduction procedure can be found in Refs. 3 and 4. The recording and calibrating procedures for this type gage are summarized in Table 2.

2.5.3 Hot-Wire Anemometry

Flow fluctuation measurements were made using hot-wire anemometry techniques. The constant-current hot-wire anemometer instrumentation with auxiliary electronic equipment was furnished by the VKF. The anemometer current control (Philco-Ford Model ADP-13) which supplies the heating current to the sensor is capable of maintaining the current at any one of 15 preset levels individually selected using push-button switches. The anemometer amplifier (Philco-Ford Model ADP-12) which amplifies the wire-response signal contains the circuits required to electronically compensate the signal for thermal lag due to the finite heat capacity of the wire. A square-wave generator (Shapiro/Edwards Model G-50) was used in determining the time constant of the sensor whenever required. The sensor heating current and mean voltage were fed to autoranging digital voltmeters for a visual display of these parameters and to the VKF Bell and Howell model VR3700 B magnetic tape machine for recording. The sensor response a-c voltage was fed to an oscilloscope for visual display of the raw signal and to a wave analyzer (Hewlett-Packard Model 8553B/8552B) for visual display of the spectra of the fluctuating signal and was recorded on magnetic tape for subsequent analysis by the VKF. A detailed description of the hot-wire anemometer instrumentation is given in Ref. 5.

The analog response signals from the hot-wire anemometer were recorded on the VKF Bell and Howell model VR3700 B magnetic tape machine in the FM mode. Each channel was calibrated and adjusted to have a signal-to-noise ratio of 35 db for a 1.000 volt rms output. The tape machine frequency response was +1 to -3 db over a d-c frequency range to 500 kHz. In the present calibration, a sine wave generator was used to check each channel at several discrete frequencies, using an rms-voltmeter which is periodically checked on 1, 10, and 100 volt ranges. All magnetic tape recordings were made at a tape speed of 120 in./sec.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS AND PROCEDURES

3.1.1 General

A summary of the nominal test conditions is given below.

M	PT, psia	TT, °R	PT2, psia	P, psia	RE/FT x 10^{-6}
8.0	225	1350	1.91	0.023	1.0
↓	580	↓	4.92	0.060	2.5
	800		6.79	0.082	3.5

A test summary showing all configurations tested and the variables for each is presented in Table 3.

In the VKF continuous flow wind tunnels (A, B, C), the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, and the model is injected into the airstream, and the fairing doors are closed. After the data are obtained, the model is retracted into the tank and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run. The sequence is repeated for each configuration change.

The probes were positioned during each boundary layer survey along the normal to the model surface by an automatic stepping device which was programmed for step size and time duration.

3.1.2 Data Acquisition

A laminar boundary layer over the forward and midportions of the body with transition beginning near the aft end was the desired operating condition for the equilibrium wall temperature survey study. However, the boundary layer condition could only be determined for the cold wall case ($TW/TT \approx 0.4$) because of heat gage limitations. The cold wall boundary layer conditions were determined from heat-transfer rate distributions obtained with the coaxial surface thermocouple gages. The model was injected into the tunnel flow and the heat gage output recorded continuously for approximately four (4) seconds. The model was then retracted and cooled by flowing air over its surface to obtain a uniform wall temperature, near room temperature, prior to injection into the tunnel flow for the next run.

As a result of the requirement to have laminar flow over most of the model's surface at a free-stream Mach number of 8, the free-stream Reynolds number was varied depending on the blunt nose configuration. The sharp configuration was tested at a free-stream Reynolds number of 1.0×10^6/ft, the 3% bluntness at 2.5×10^6/ft, and both the 10% and 40% bluntness at 3.5×10^6/ft, which is near the maximum operating conditions in VKF Tunnel B.

Surface pressure distribution data were obtained on each blunt nose configuration at the desired Mach number-Reynolds number condition.

Flow field surveys were obtained only after the model had reached a state of temperature equilibrium. The model was positioned in a roll orientation (ROLL = -90 Deg) to avoid interference of the surface instrumentation on the flow field being surveyed.

Mean-flow boundary layer profiles were obtained on the sharp and 3% bluntness configurations at six stations (approximately every 5 inches starting 5 inches from the base) using pitot pressure and total temperature probes. Similar mean flow profiles were obtained on the 40% bluntness configuration at midbody and 5 inches from the base. The profiles extended from near the model's surface to a height of 2 to 3 δ (boundary layer thickness) in a direction normal to the surface. Generally a profile consisted of from 20 to 30 points located approximately 0.010 inches apart. Measurements were recorded for processing by the data system only after pressure stablization had been achieved. Model wall pressure and temperature data were measured simultaneously with the probe data. Table 4 indicates the stations at which surveys were made on each configuration and relates station distance, X, to surface distance.

The survey probe height relative to the model was monitored using a high-resolution (1224 lines/frame, 30 frames/sec) closed-circuit television (CCTV) system (Fig. 6). The camera was fitted with a telescopic lens system which gave a magnification factor of 38 (from tunnel centerline to monitor picture). The probe and model were back-lighted using the collimated light beam of the Tunnel B shadowgraph system which was aligned with respect to the model just prior to testing. Calibration of the system was made using a wire of 0.0095-in. diameter positioned at the test section centerline. Subsequent measurements were made on the face of the monitor picture tube using scales specially prepared from the calibration images. The field of view was approximately 0.3 in. (axially) by 0.2 in. (vertically) and a spacing of 0.001 in. was easily discernible. The camera was isolated from tunnel vibrations by mounting it with the optics system which has a foundation separate from that of the tunnel. Small vibrations of the model were observable, and, using the calibrated viewing screen, it was possible to estimate the vertical motions of the model as being of the order of ±0.001 in. The probe vertical vibrations when present were estimated to be of the order of ±0.002 in. Positioning

of the probe at a desired location (in terms of X) on the model, within the field of view of the CCTV system, was achieved using a graticule, marked in 0.1 in. increments of X and indicating a 0.1-in. distance normal to the model surface. The graticule was viewed using the Tunnel B shadowgraph system.

The primary test technique for the present investigation was hot-wire anemometry; and considerable effort was directed toward obtaining qualitative and quantitative hot-wire anemometer profile data. The mean boundary layer profile data were necessary to define the flow environment in the vicinity of the hot wire.

The hot-wire anemometer profile surveys were of three general types: (1) continuous traverse surveys to map a particular region, (2) qualitative boundary layer profile surveys and (3) quantitative hot-wire data at particular point locations within a survey.

To acquire data of the first category, with the hot-wire anemometer at a single sensitivity (heating current), the probe was swept in a continuous manner from near the model's surface outward to a distance of approximately 2δ. This type survey was made on the sharp configuration at 28 stations starting near the aft end of the model and moving forward in approximately one-inch increments. Similar surveys were made on the 3% bluntness configuration at 25 stations, the 10% configurations at 2 stations, and at 3 stations on the 40% bluntness configuration. The reason for fewer profiles on the blunter configurations was the difficulty with survival of the hot-wire probes in the blunt cone environment. Based upon previous experience, it is believed that the higher unit Reynolds number condition used for the blunt configuration was the principal factor in the wire's low survival rate.

The hot-wire anemometer qualitative boundary layer profile data were obtained using a hot-wire anemometer probe and a total temperature probe. The general procedure was identical to the mean flow boundary layer profile sequence with the exception that much less time was needed for recording data at each point in the profile (no stabilization time required as with the pitot pressure). This type of profile was made at selected model stations, generally at three-inch intervals along the model's surface, at a single wire sensitivity as the wire was traversed away from the model in increments of 0.010 inches.

The continuous-traverse surveys with the hot-wire anemometer were generally characterized by a single peak in the plot of the anemometer response. The peak was defined as the location of the maximum disturbance energy in the flow field at the given model axial station. At each of these peaks, quantitative hot-wire data were taken by stepping through a sequence of 11 wire sensitivities.

Both the hot-wire anemometer qualitative boundary layer profile data and the quantitative data at the maximum disturbance energy locations were recorded on magnetic tape at a tape speed of 120 in./sec.

A calibration of the recovery factor of the total temperature probe as a function of local Reynolds number was made in the free-stream flow of the Tunnel B test section. A Reynolds number variation was produced by varying PT while maintaing TT at a nominally constant level. The free-stream total temperature was assumed equal to the measured stilling chamber temperature, TT. The range of Reynolds number covered by a typical calibration and that required in the data reduction are shown in Fig. 7. The fairing shown in Fig. 7, a straight-line least-squares fit of the calibration data, was used for the data reduction over the required range.

3.1.3 Hot-Wire Anemometer Probe Calibration

The evaluation of flow fluctuation measurements made using hot-wire anemometry techniques requires a knowledge of certain thermal and physical characteristics of the wire sensor employed. In applications of the hot wire to wind tunnel tests by the VKF, two complementary calibrations are used to evaluate the wire characteristics needed. The first calibration of each hot-wire probe is performed in the instrumentation laboratory prior to the testing: the probe is placed in an oven and the resistance of the wire is determined as a function of applied wire heating current at several oven temperatures between room temperature and 1000°F. The wire reference resistance at 32°F, and the thermal coefficient of resistance, also at 32°F, are obtained from the results; and the wire aspect (length-to-diameter) ratio is determined, using the wire resistance per unit length specified by the manufacturer with each supply of wire. Moreover, it has been found by the VKF that the exposure of the probes to the elevated temperatures of the oven calibration often serves to eliminate probes with inherent weaknesses.

Each probe used for flow field measurements is calibrated in the wind tunnel free-stream flow to obtain the heat-loss coefficient (Nusselt number) and the temperature recovery factor characteristics of the wire sensor as a function of local Reynolds number. The variations of Reynolds number in the free stream are obtained by varying the tunnel total pressure PT while holding the tunnel total temperature TT at a nominally constant level. The resulting relationships are expressed in equation form and are used to determine the values of the various wire sensitivity parameters required in the reduction of the quantitative measurements.

3.2 DATA REDUCTION

The various types of data obtained during the test entry are summarized in Table 3. DATA TYPE callouts used are 2, 3, 4, 6, 9 and Heat Transfer.

A very limited quantity of hot-wire anemometer measurements is tabulated in the data package accompanying this report. The only data presented are the anemometer output rms voltage measured during the hot-wire anemometer qualitative boundary layer profile series (DATA TYPE 3) and the free-stream conditions used in the anemometer probe calibrations (DATA TYPE 9). Hot-wire current and mean voltage measurements are also given for the TYPE 9 data. The analysis of the hot-wire anemometer data including modal and spectral analyses of the recorded signals is not included in the present report.

The mean flow boundary layer data (DATA TYPE 4) includes an evaluation of several boundary layer parameters, namely: the boundary layer thickness, displacement thickness, and momentum thickness. To determine these parameters requires a knowledge of the surface pressure and temperature at the survey station, the corrected total temperature measurement, a method for defining the boundary-layer edge, and the height relationship between the pitot and total temperature probes.

The model surface pressures used in the boundary-layer calculations, which are tabulated in TYPES 3 and 4 data results, were determined using a fairing of the measured pressure distributions (TYPE 2 DATA) for the case of the 3% bluntness configuration, and a fairing of measured pressure distributions extrapolated with the aid of theoretical solutions for regions where no pressure measurements were made for the remaining configurations. The static pressure across the boundary layer was assumed constant and equal to the surface value at each survey station. The surface pressure distributions used are shown in Fig. 8.

The surface temperature used was determined from the measured surface thermocouple data in the vicinity of the survey station. A three point interpolation routine was used to calculate the wall temperature at the exact wall location using the nearest functioning thermocouples.

The hot-wire anemometer probe was located 0.125 in. to the right of the pitot probe (looking downstream with the pitot probe in line with the model's vertical centerline), and the total temperature probe was located 0.125 in. to the left. Allowance was made for this in determining the height of each probe off the model surface. Also, there was normally some misalignment in the vertical direction, which was determined from the high resolution closed-circuit television system during the test and verified after the test from photographs taken of

the probes at the initial point of each survey. With these considerations the heights of the boundary-layer survey probes above the model surface, in the direction normal to the surface, were calculated for each profile station and are given in the tabulations and plotted data.

The boundary-layer surveys are tabulated in terms of the pitot pressure probe height. The total temperature probe measurement corresponding to each pitot probe height was determined using a three-point interpolation scheme. The calculation of local Reynolds number for use with the total temperature probe recovery factor calibration was initiated by using the uncorrected total temperature measurement then an iteration scheme followed until successive values of "corrected" total temperature were within 0.1 deg R. For those surveys where the pitot probe was positioned in the probe head slightly lower than the total temperature probe (closer to the model), the corrected total temperature at the corresponding pitot heights near the surface were determined from a second order curve fit using three points, i.e., the model surface temperature and the corrected total temperature at the first two probe heights where it was available.

The thickness of the model boundary layer on any given profile was inferred from the profile of the local uncorrected total temperature value (TTLU). The boundary-layer surveys generally extended well beyond the estimated boundary-layer thickness. Uncorrected total temperatures measured above the boundary-layer edge (in the shock layer) remained constant or essentially independent of the probe height. The height at which this constant portion of the profile began was defined as the edge of the boundary layer. There was generally a very distinct "overshoot" in the uncorrected total temperature profile just prior to the onset of the constant portion of the profile. The profile of the velocity ratio (local velocity-to-velocity at the edge) was then determined and the height corresponding to a ratio of 0.995 was found by interpolation and arbitrarily designated as the boundary-layer total thickness, DEL. Displacement and momentum thicknesses were determined by integration using standard data reduction procedures.

3.3 UNCERTAINTY OF MEASUREMENTS

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of Standards (NBS), Ref. 6. Measurement uncertainty (U) is a combination of bias and precision errors defined as:

$$U = \pm (B + t_{95}S)$$

where B is the bias limit, S is the sample standard deviation, and t_{95} is the 95th percentile point for the two-tailed Student's "t" distribution, which for degrees of freedom greater than 30 equals 2.

Estimates of the measured data uncertainties for this test, including the basic hot-wire anemometer measurements included in this report, are given in Table 2a, b. Estimates of uncertainties in flow fluctuations derived from the hot-wire anemometer measurements and in other calculated flow survey parameters fall outside the scope of this project effort. In general, measurement uncertainties are determined from in-place calibrations through the data recording system and data reduction program.

The propagation of the estimated bias and precision errors of the measured data through the data reduction and analysis was made in accordance with Ref. 6, and is summarized in Table 2c.

4.0 DATA PACKAGE PRESENTATION

Boundary-layer profile data, model surface data, probe calibration data, and basic hot-wire anemometer data from the test were reduced to tabular and graphical form for presentation as a Data Package. Examples of the basic data type tabulations are shown in Appendix III.

Illustrations of the heat transfer rate distribution data and the qualitative hot-wire anemometer profile results are shown in Figs. 9 and 10, respectively. Figure 11 is an example of the mean flow boundary-layer survey results for the 10% bluntness configuration at a particular survey station. The tabulations in the appendix correspond to these plotted data.

5.0 REFERENCES

1. Test Facilities Handbook (Eleventh Edition). "Von Kármán Gas Dynamics Facility, Vol. 3." Arnold Engineering Development Center, June 1979.

2. Doughman, E. L. "Development of Hot Wire Anemometer for Hypersonic Turbulent Flows," Philco-Ford Corporation Publication No. U-4944, December 1971; and The Review of Scientific Instruments, Vol. 43, No. 8, August 1972, pp. 1200-1202.

3. Trimmer, L. L., et al. "Measurements of Aerodynamic Heat Rates at the AEDC Von Kármán Facility," Reprint from ICIASF 1973 Record, International Congress on Instrumentation on Aerospace Simulation Facilities, September 1973.

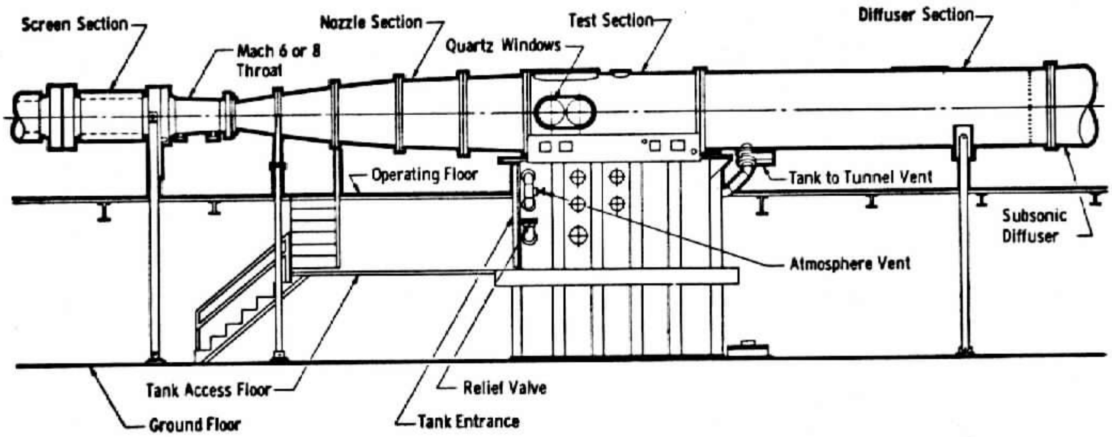
4. Cook, W. J. and Felderman, E. J. "Reduction of Data from Thin-Film Heat Transfer Gages: A Concise Numerical Technique," AIAA Journal Vol. 4, No. 3, March 1966, p. 561.

5. Donaldson, J. C., Nelson, C. G., and O'Hare, J. E. "The Development of Hot Wire Anemometer Test Capabilities for $M_\infty = 6$ and $M_\infty = 8$ Applications," AEDC-TR-76-88 (AD A029570), September 1976.

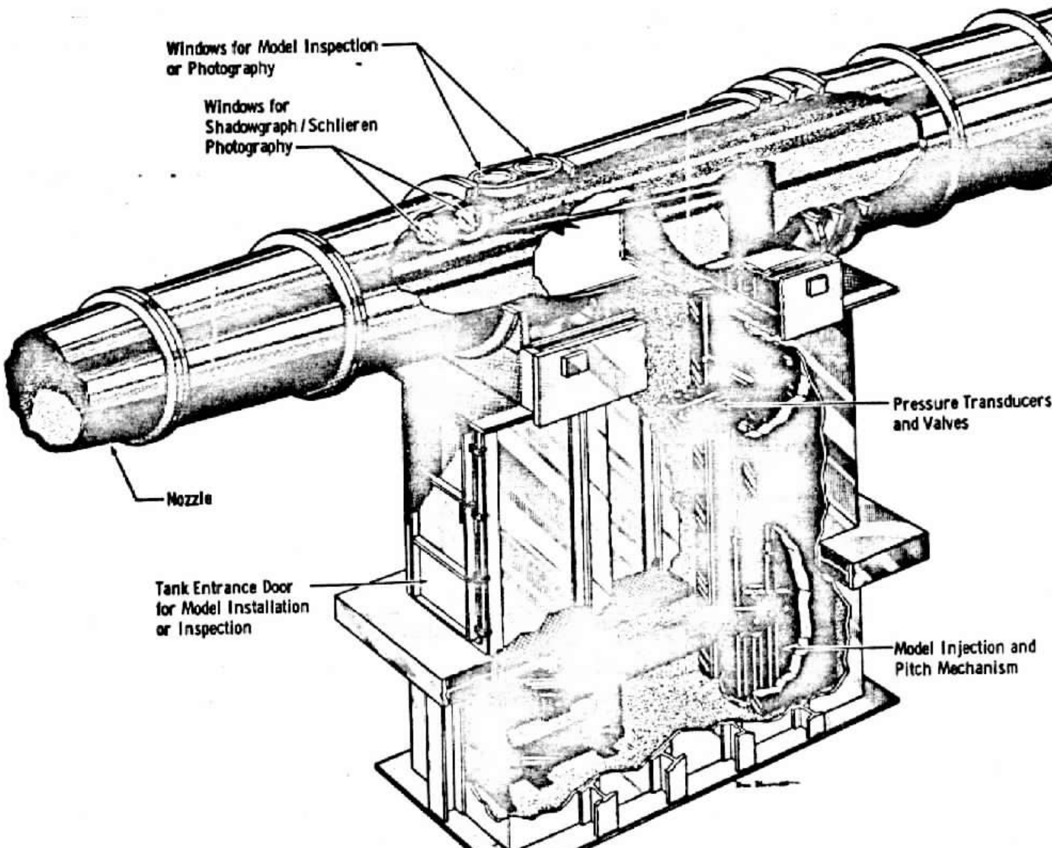
6. Thompson, J. W., et al. "Handbook Uncertainty in Gas Turbine Measurements," AEDC-TR-73-5 (AD755356), February 1973.

APPENDIX I

ILLUSTRATIONS



a. Tunnel assembly



b. Tunnel test section

Fig. 1. Tunnel B

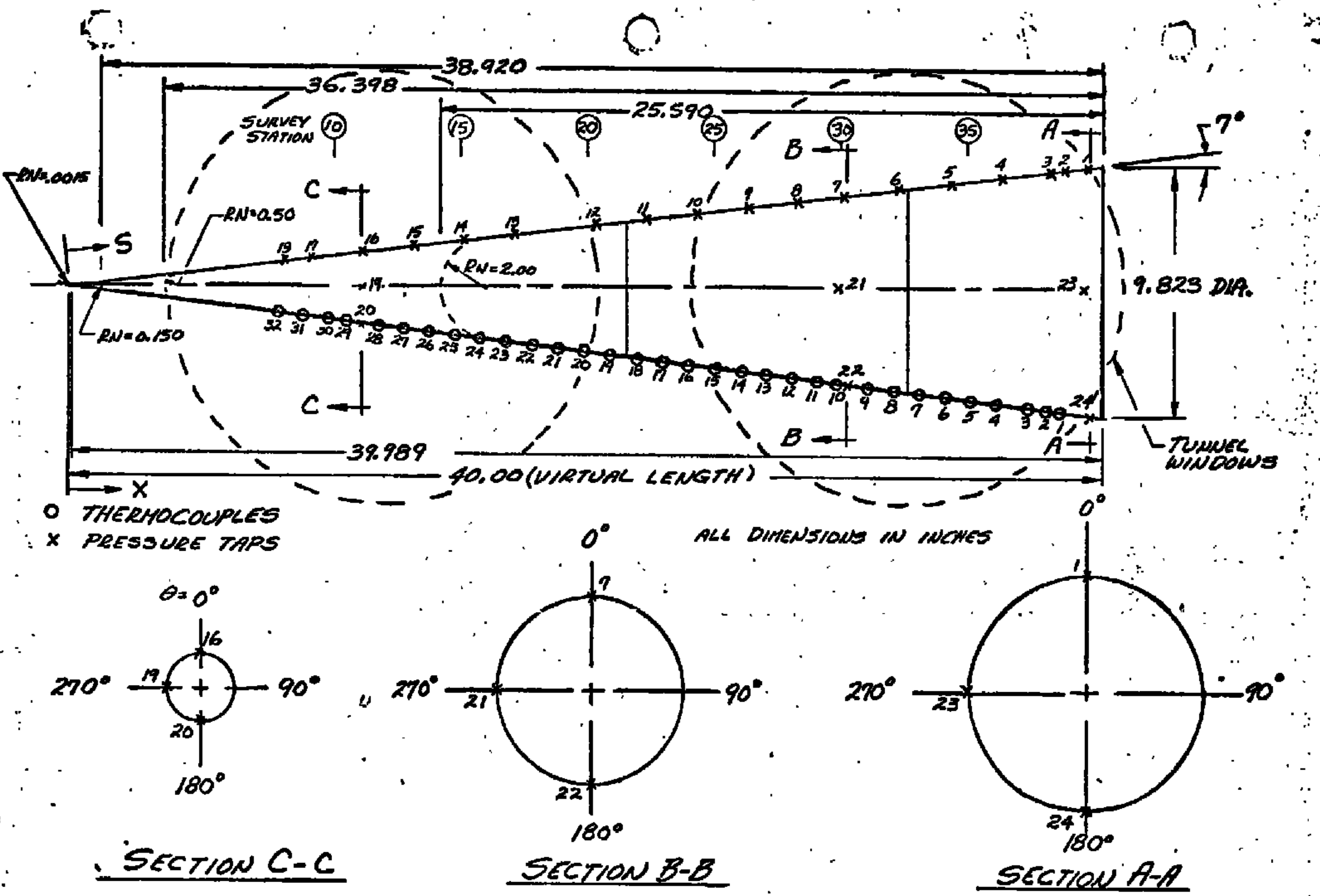


FIG. 2 MODEL GEOMETRY AND GAGE LOCATIONS

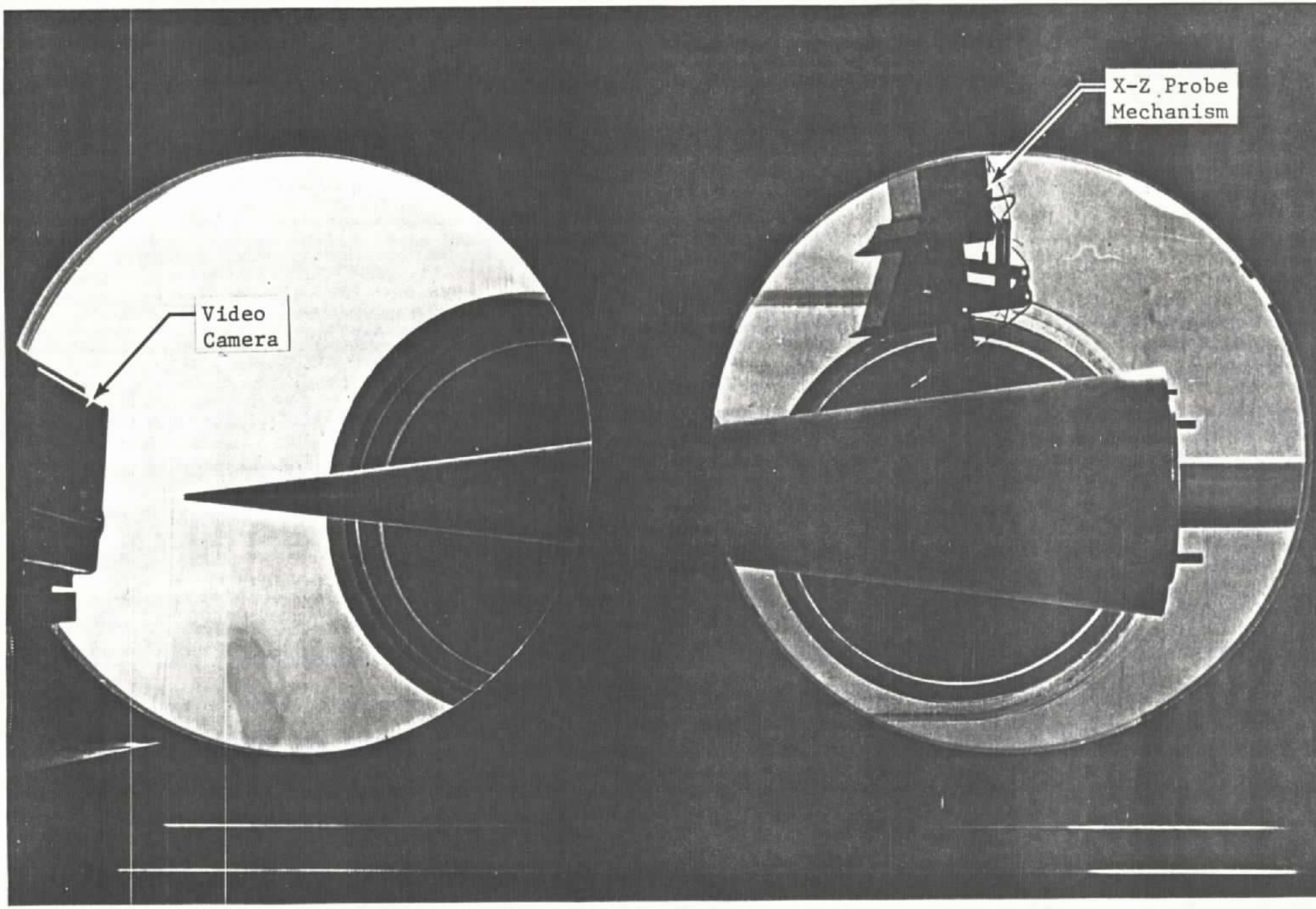
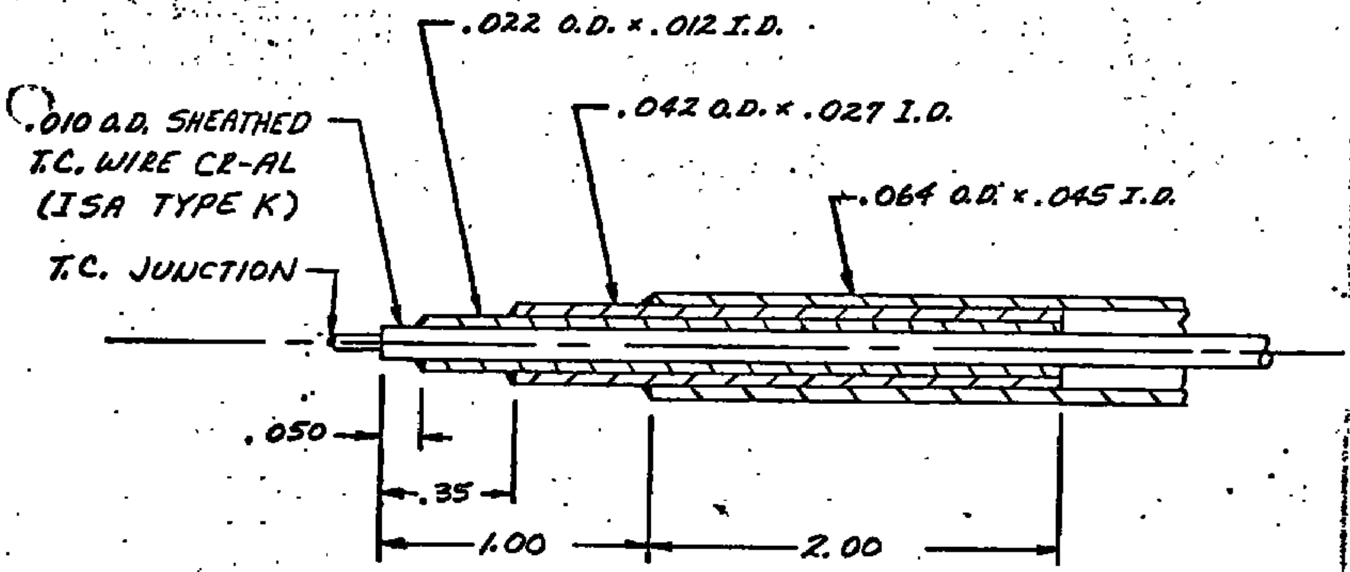
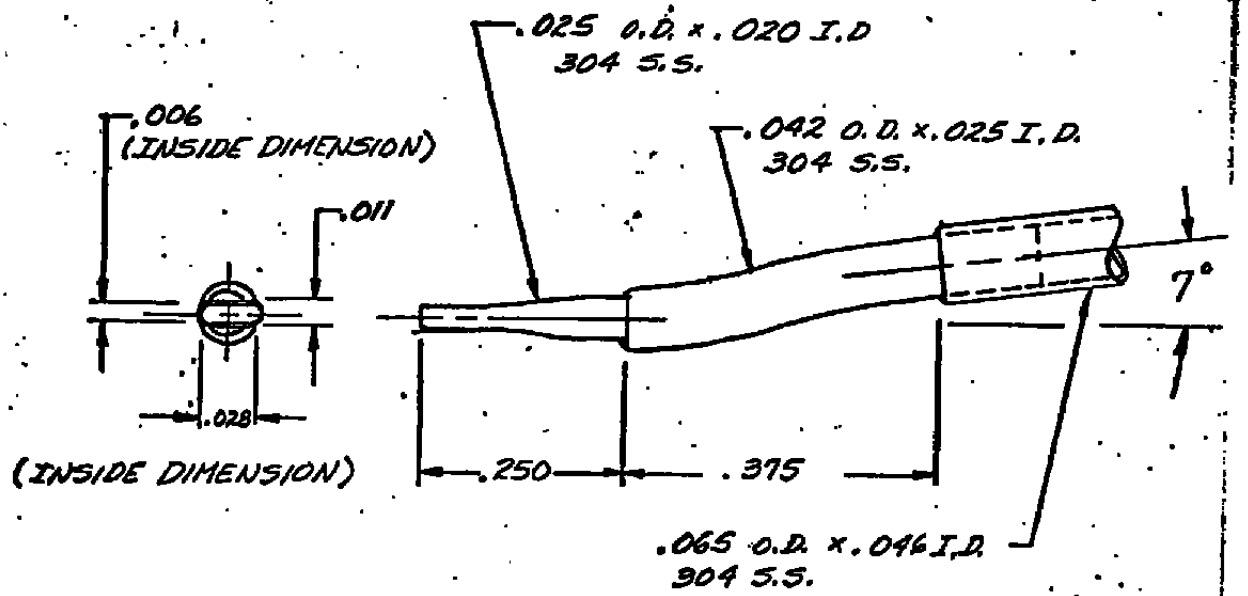


Fig. 3 Test Installation



b) TOTAL TEMPERATURE PROBE

ALL DIMENSIONS IN INCHES



a) PITOT-PRESSURE PROBE

FIG. 4 PROBE DETAILS

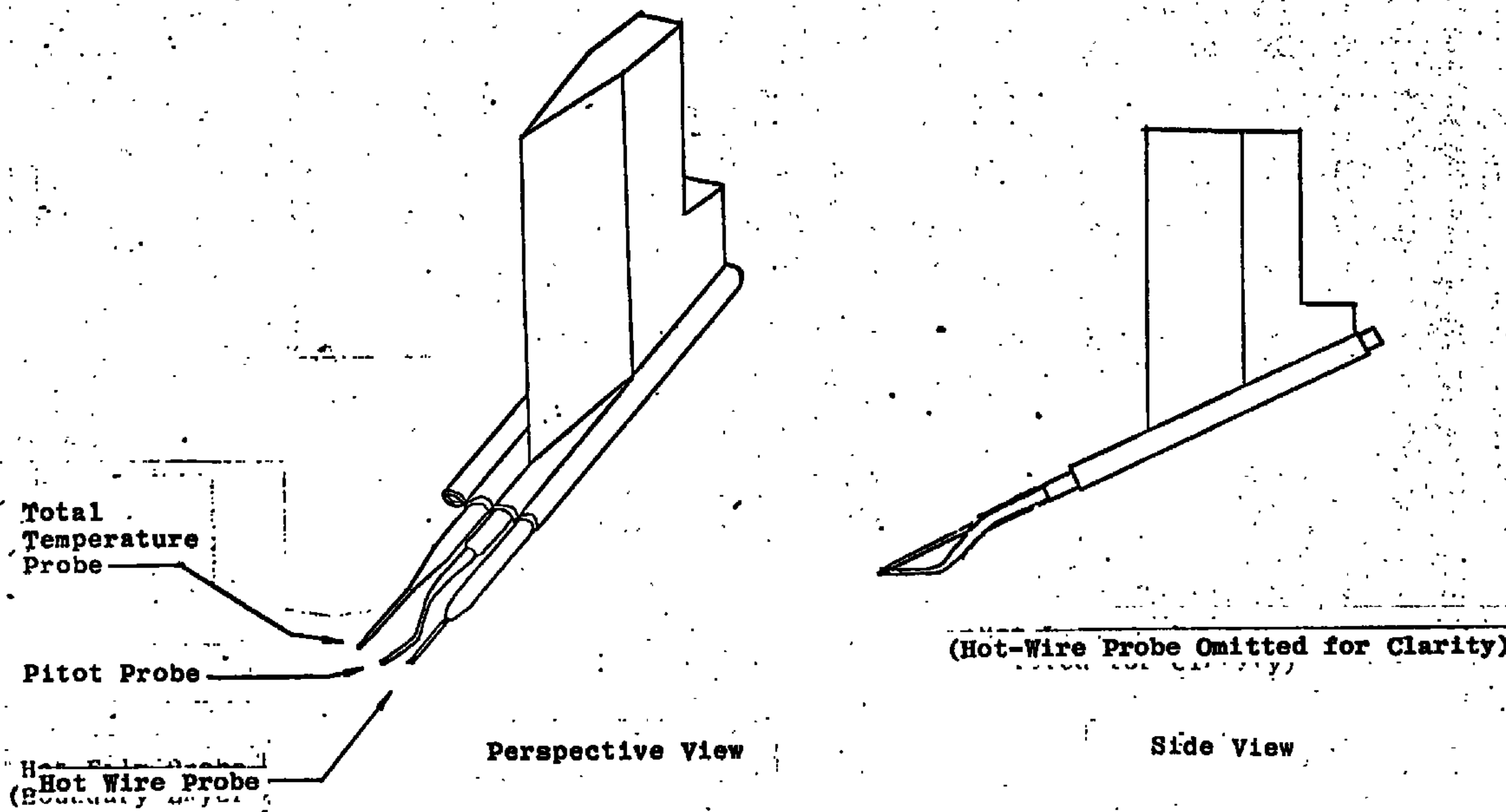


Fig. 5 Sketch of Survey Probe Rake

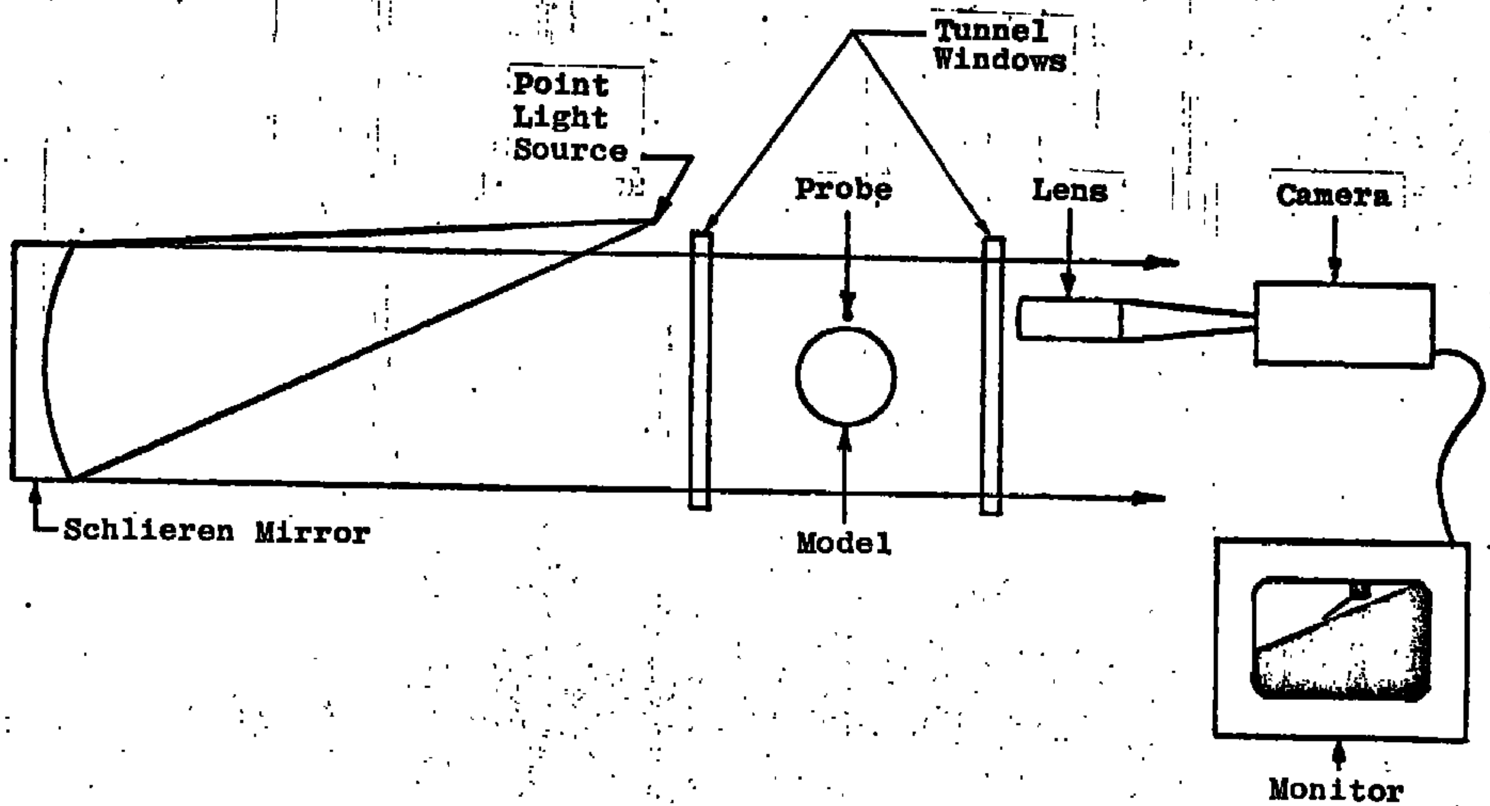


Figure 6 Closed-Circuit Television System

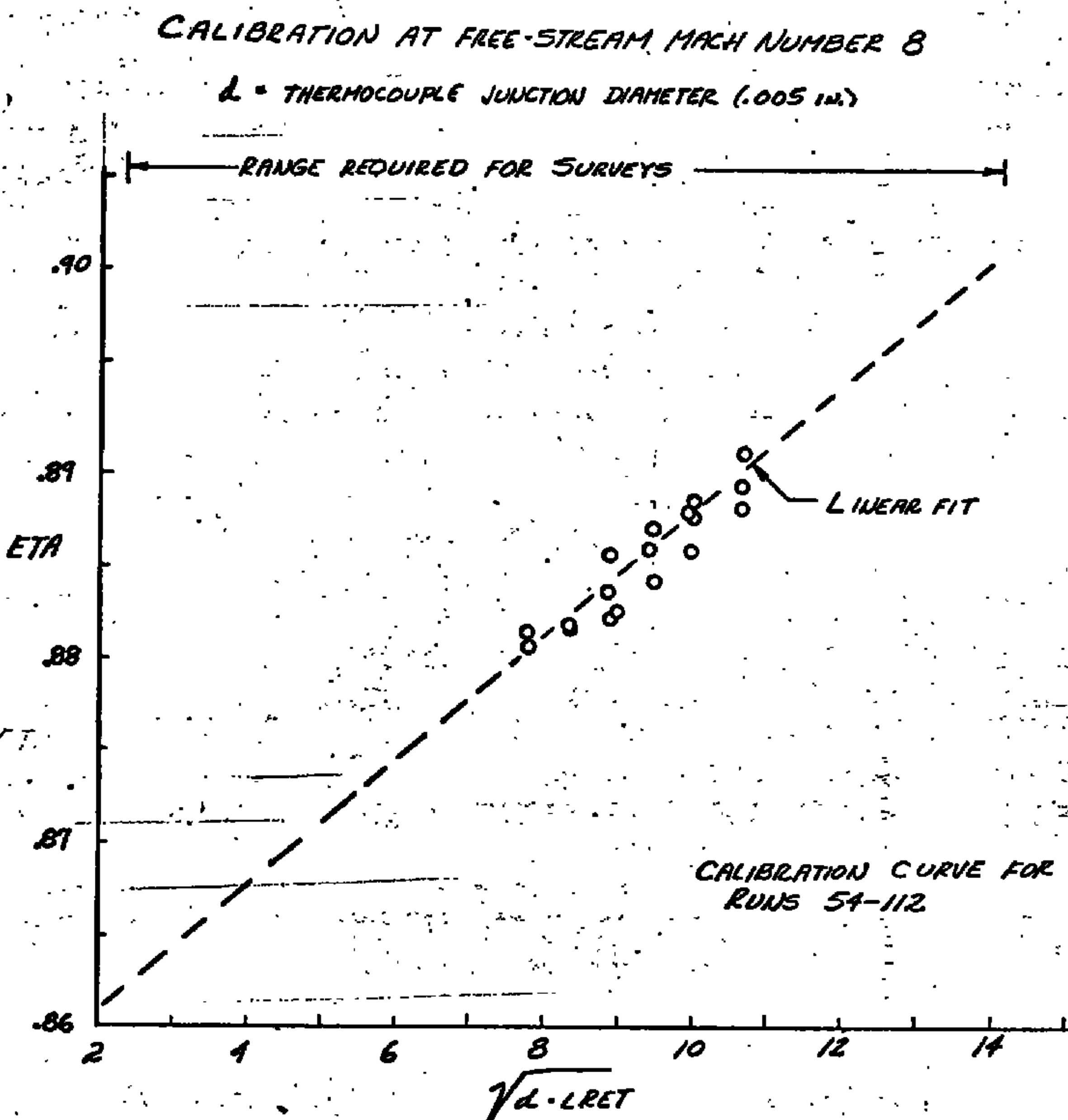


FIG 7 TYPICAL TOTAL TEMPERATURE PROBE CALIBRATION

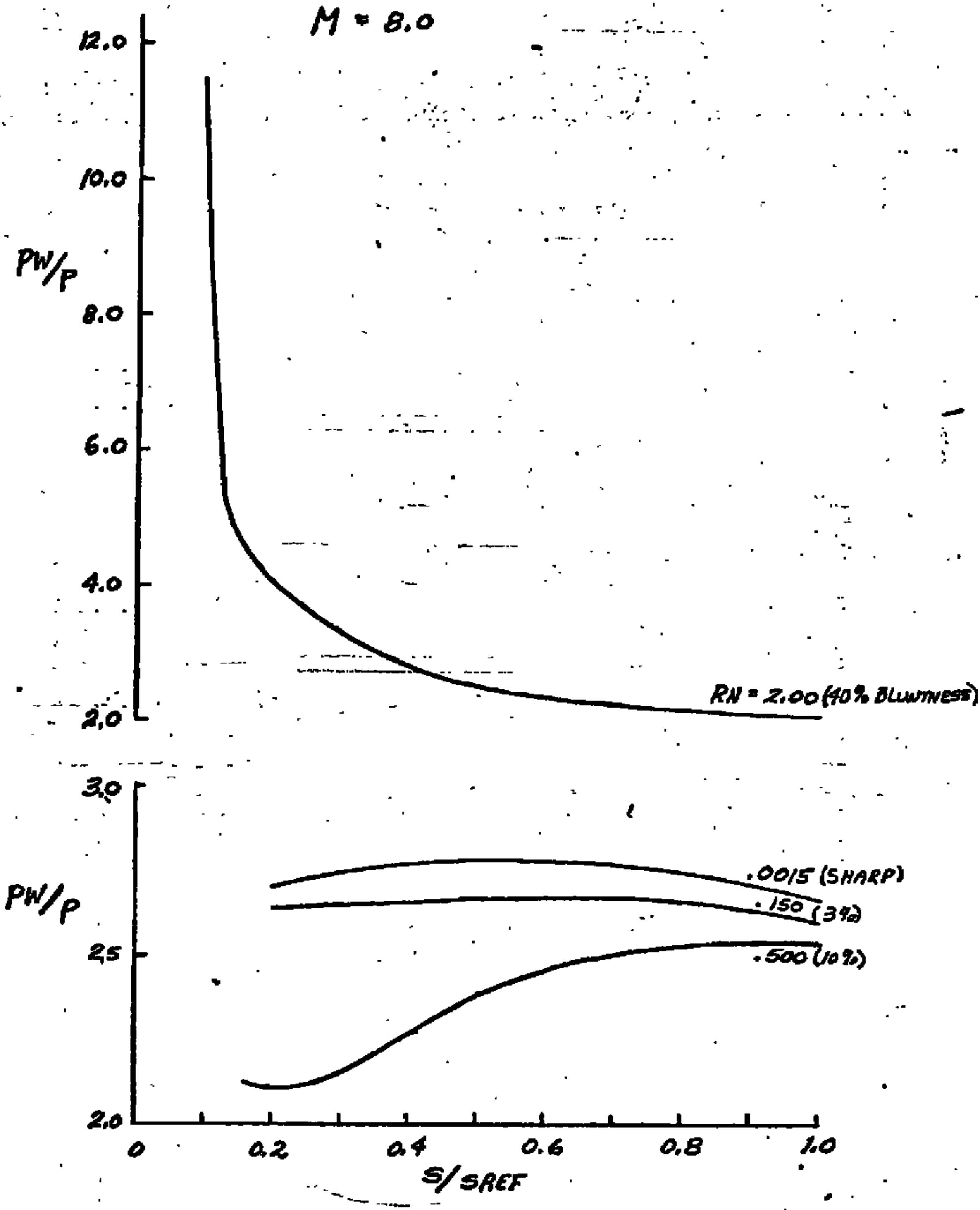
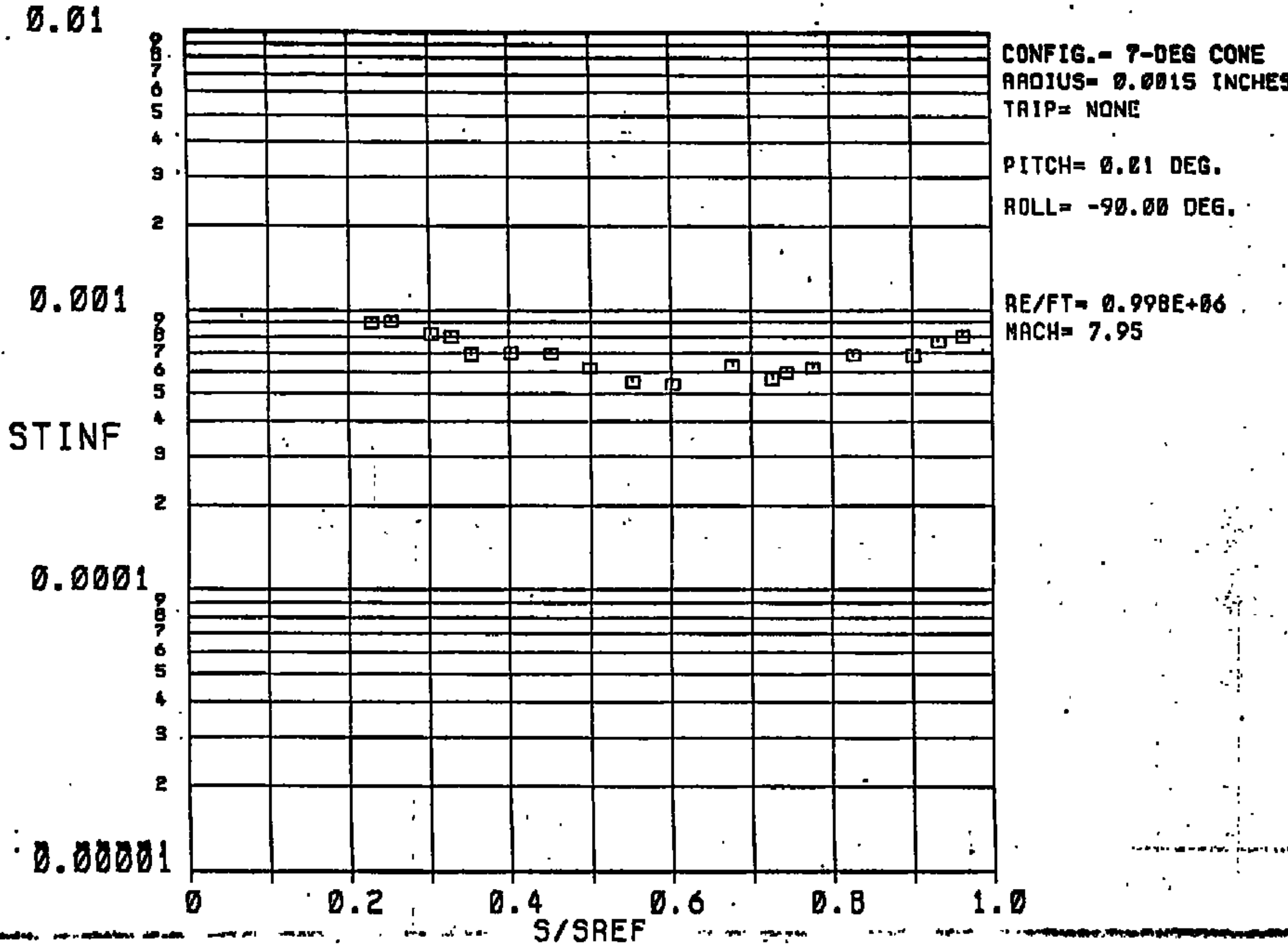


FIG. 8 MODEL SURFACE PRESSURE DISTRIBUTIONS

V41B-2
AFOSR/AFFDL



RUN = 5

FIG. 9 ILLUSTRATION OF HEAT-TRANSFER DISTRIBUTION RESULTS

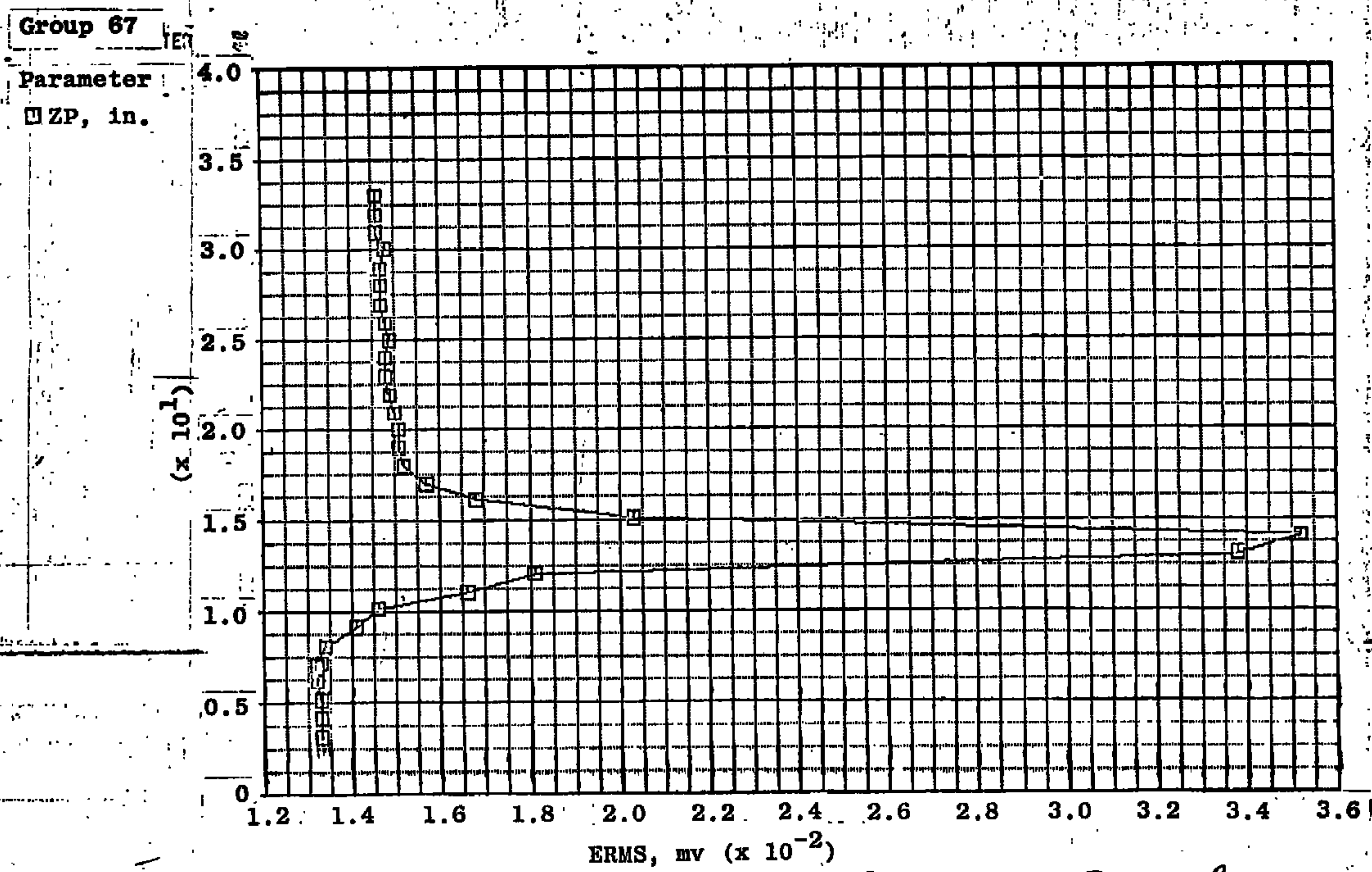


FIG. 10 ILLUSTRATION OF QUALITATIVE HOT-WIRE ANEMOMETER PROFILE RESULTS

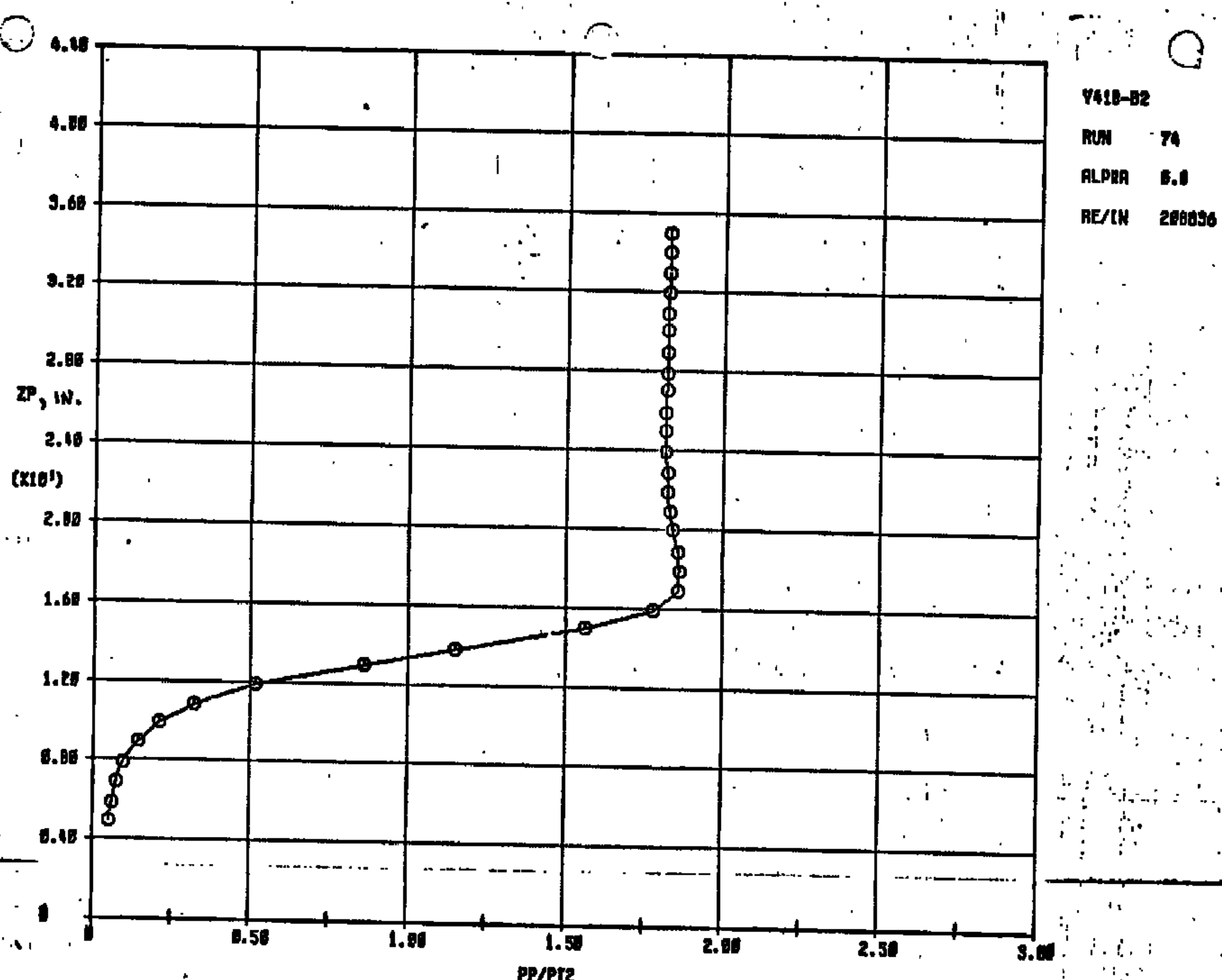


FIG. 11 ILLUSTRATION OF MEAN FLOW BOUNDARY LAYER SURVEY RESULTS

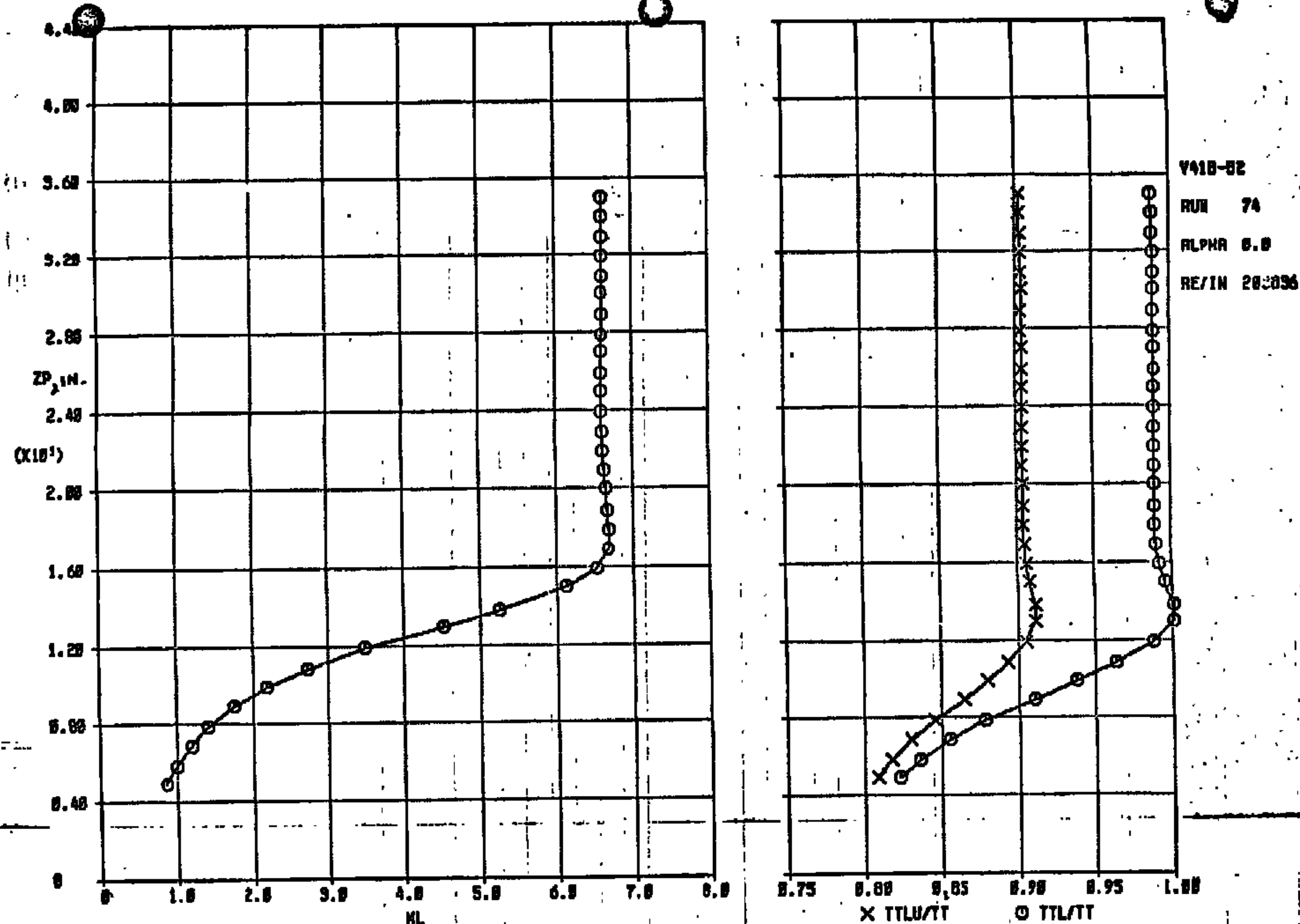


FIG. 11 CONTINUED

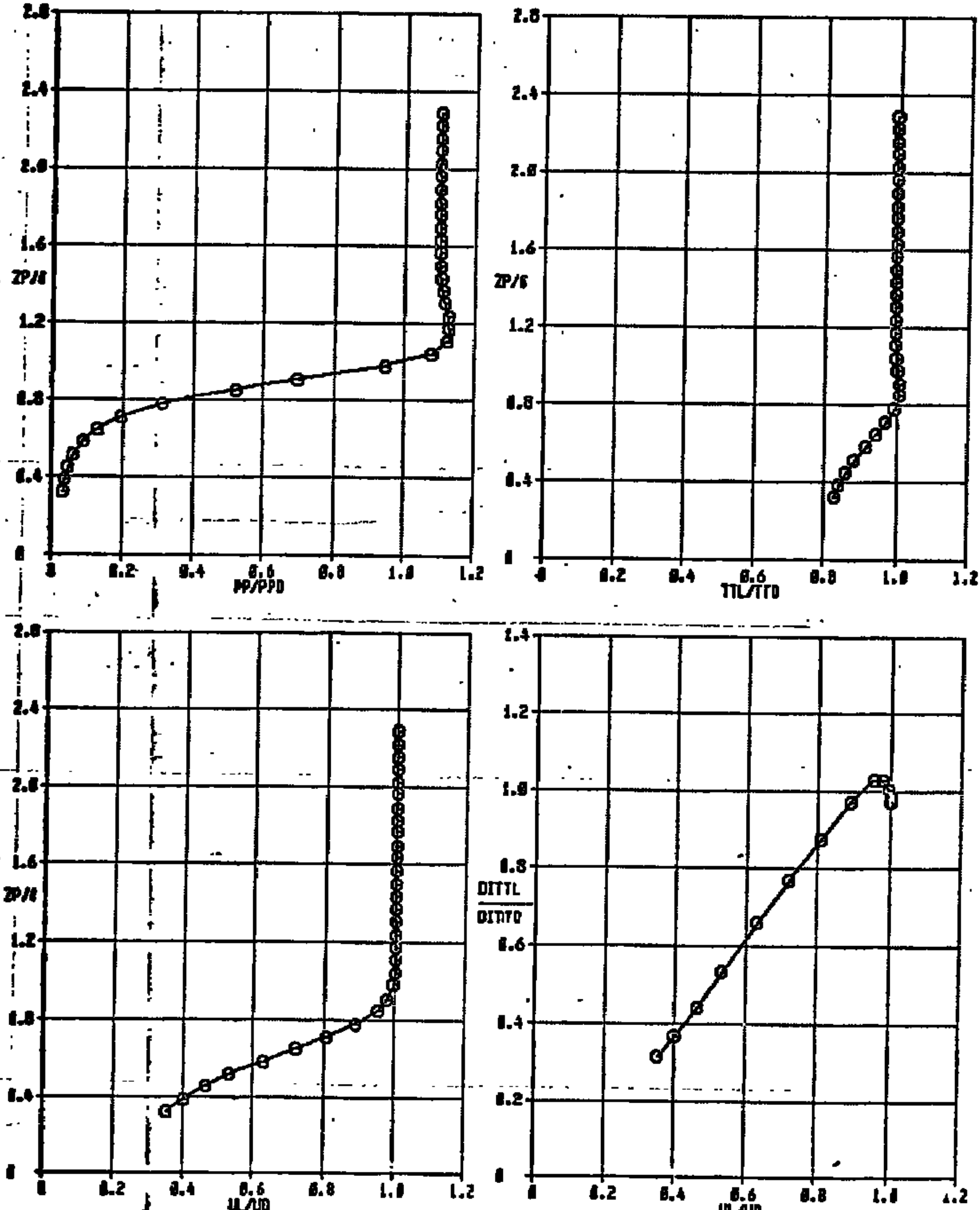


FIG. 11 CONTINUED

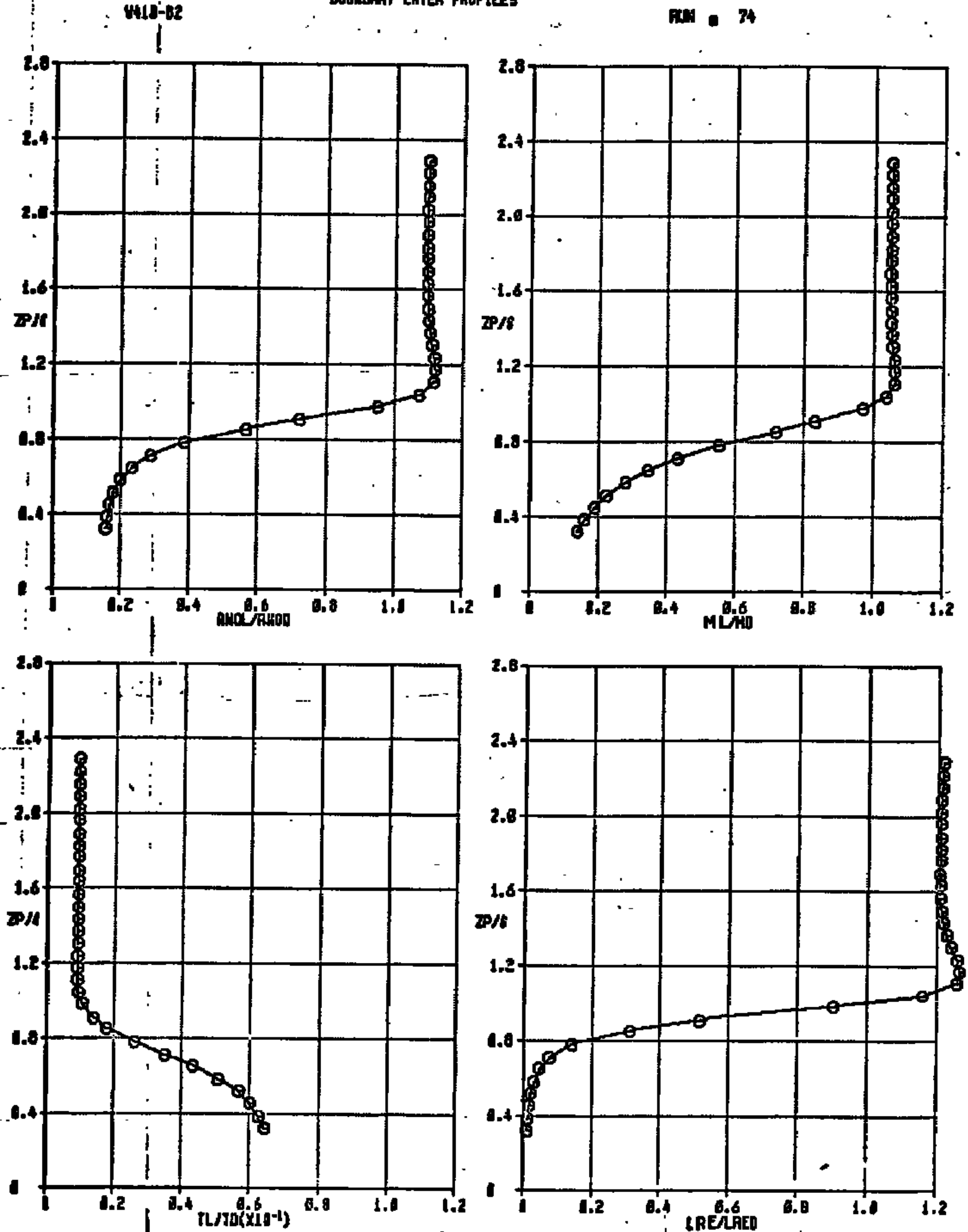


FIG. 11 CONCLUDED

APPENDIX II

TABLES

TABLE 1 MODEL INSTRUMENTATION LOCATIONS

a) PRESSURE TAPS

TAP NO.	THETA DEG.	S, IN. NOSE #1 (RN=0.0015)	#2 (0.150)	#3 (0.500)	#4 (2.000)
1	0	39.791	38.797	36.453	26.410
2		38.791	37.797	35.453	25.410
3		38.291	37.297	34.953	24.910
4		36.291	35.297	32.953	22.910
5		34.291	33.297	30.953	20.910
6		32.231	31.237	28.893	18.850
7		30.231	29.237	26.893	16.850
8		28.231	27.237	24.893	14.850
9		26.231	25.237	22.893	12.850
10		24.231	23.237	20.893	10.850
11		22.231	21.237	18.893	8.850
12		20.141	19.147	16.803	
13		17.141	16.147	13.803	
14		15.141	14.147	11.803	
15		13.141	12.147	9.803	
16		11.141	10.147	7.803	
17		9.141	8.147	5.803	
18		8.141	7.147	4.803	
19	270	11.141	10.147	7.803	
20	180	11.141	10.147	7.803	
21	270	30.231	29.237	26.893	16.850
22	180	30.231	29.237	26.893	16.850
23	270	39.791	38.797	36.453	26.410
24	180	39.791	38.797	36.453	26.410

TABLE 1 CONCLUDED

A) THERMOCOUPLE LOCATIONS

T/C NO.	THETA DEG	S, IN NOSE #1 (RN=0.0015)	#2 (0.150)	#3 (0.50)	#4 (2.00)
1	180	38.790	37.796	35.452	25.409
2		38.290	37.296	34.952	24.909
3		37.590	36.596	34.252	24.209
4		36.290	35.296	32.952	22.909
5		35.290	34.296	31.952	21.909
6		34.290	33.296	30.952	20.909
7		33.290	32.296	29.952	19.909
8		32.230	31.236	28.892	18.849
9		31.230	30.236	27.892	17.849
10		29.930	28.936	26.592	16.549
11		29.230	28.236	25.892	15.849
12		28.230	27.236	24.892	14.849
13		27.230	26.236	23.892	13.849
14		26.230	25.236	22.892	12.849
15		25.230	24.236	21.892	11.849
16		24.230	23.236	20.892	10.849
17		23.230	22.236	19.892	9.849
18		22.230	21.236	18.892	8.849
19		21.140	20.146	17.802	2.932
20		20.140	19.146	16.802	0.977
21		19.140	18.146	15.802	
22		18.140	17.146	14.802	
23		17.140	16.146	13.802	
24		16.140	15.146	12.802	
25		15.140	14.146	11.802	
26		14.140	13.146	10.802	
27		13.140	12.146	9.802	
28		12.140	11.146	8.802	
29		10.840	9.846	7.502	
30		10.140	9.146	6.802	
31		9.140	8.146	5.802	
32		8.140	7.146	4.802	

TABLE 2. ESTIMATED UNCERTAINTIES

a. Basic Static Measurements

Parameter Designation	Steady-State Estimated Measurement*: Precision Index (S): Percent of Reading	Precision Index (S): Unit of Measurement	Precision Index (S): Degree of Freedom	Bias (B): Percent of Reading	Bias (B): Unit of Measurement	Uncertainty ±(B + $t_{95}S$): Percent of Reading	Uncertainty ±(B + $t_{95}S$): Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
PT,psia		±0.02 ±0.02 ±0.11 ±0.11	>30 >30 >30 >30	 ±0.25 ±0.25	±0.26 ±0.58	 ±0.27 ±0.27	±0.30 ±0.80	<104 <200 <232 <1000	Bell and Howell Variable Capacitance Transducer	Digital Data Acquisition System Analog to Digital Converter	In-place Air Dead Weight Calibration
TT,°F		±1 ±1	>30	 ±0.375	±2	 ±0.380	±4	<530 <2300	Chromel-Alumel Thermocouple	Doric Temperature Instrument Digital Multiplexer	Thermocouple Verification of NBS Conformic Voltage Substitution Calibration
ALPHA,deg		±0.025	>30		0*		±0.05	<15	Potentiometer	Digital Data Acquisition System Analog to Digital Converter	
PHI,deg		±0.15	>30		0*		±0.30	<180	↓		Precision Inclinometer
PP,psia		±0.0025	>30	±0.038			±0.005	<15	Druck Flush Diaphragm 4-arm Strain Gage	↓	In-place Air Dead Weight Calibration
TTTU,°F		±1 ±1	>30	 ±0.375	±2	 ±0.380	±4	<530 <2300	Unshielded CR-AL Thermocouple	Digital Data Acquisition System Analog to Digital Converter	Thermocouple Verification of NBS Conformic Voltage Substitution Calibration
Ps,psia standard pressure system		±0.00075	>30				±0.0015	<0.5	MKS Baratron	↓	In-place Air Dead Weight Calibration
TDRK,°F		±1	>30		±2		±4	<530	CR-AL Thermocouple	Doric Temperature Instrument/Digital Converter	Thermocouple Verification of NBS Conformic Voltage Substitution Calibration
TW,°F		±1 ±1	>30	 ±0.375	±2.2	 ±0.380	±4.2	<600 <1600	Cr-CN Coax Thermocouple	Digital Data Acquisition System Analog to Digital Converter	
ZP,ZA,ZT,in.		±0.001	>30		0*		±0.002	<0.5	Potentiometer and Optical	↓	Precision Micrometer
X(SURVEY STATION),in.		±0.005	>30		±0.020		±0.030	<35	Potentiometer Optical Gradicule	Digital Data System A/D Converter Optically Positioned Zero	↓
QDOT,BUT/ft^2-sec	±12.5		>30			±25		<1	Coaxial Surface Thermocouple	Doric Temperature Instrument/Digital Multiplexer	Radiant Heat Source and Secondary Standard Gordon Gage
ERMS,mv	± 0.5					± 1		<1000	Philco Ford Corp. Model #ADP-12/13 Hot-Wire Anemometer System	Digital Data Acquisition System Analog to Digital Converter	Precision Digital Voltmeter
CURRENT,ma	±0.5					± 1		<3	↓	↓	↓
EBAR,mv	±0.5					± 1		<325	↓	↓	↓

*Thompson, J. W. and Abernethy, R. B. et al. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973, Ref. 6.
*Assumed to be zero

VA-16 (6/79)

TABLE 3. Continued

b. Basic Measurements

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT*							Range**		Type of Measuring Device	Type of Recording Device	Method of System Calibration
	Precision Index (S)			Bias (B)		Uncertainty $\pm(B + t_{95}S)$						
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	AMPLITUDE	FREQUENCY			
Flow Turbulence	Unknown		—	Unknown		Unknown		DC to 1 volt RMS (Heating Currents up to 3 ma)	DC to 250 KHZ or 500 KHZ (freq. response band determined by filters used.	Hot Wire Anemometer System (50 microinch wire)	• Analog data recorded on tape for subsequent playback and reduction • 99 loops of data recorded on digital data acquisition system (AD converter) for each run	Wire characteristics by oven calibration Heat transfer characteristics by calibration in tunnel free-stream

*Ref. 6

**Of present measurements

TABLE 9. Concluded
c. Calculated Parameters
(at RE = 2.92×10^{5})

Parameter Designation	STEADY-STATE ESTIMATED MEASUREMENT[a]							
	Precision Index (S)			Bias (B)		Uncertainty $\pm(B + t_{95}S)$		
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	
P, psia	0.97		>30	0.25		2.19		
PT2, psia	0.68			0.25		1.61		
Q, psia	0.67			0.25		1.60		
T, °R	0.29			0.25		0.83		
V, ft/sec	0.04			0.13		0.20		
RHO, lbm/ft^3	0.70			0.36		1.76		
MU, $\frac{lbf\text{-}sec}{ft^2}$	0.29			0.25		0.83		
M	0.15			0		0.30		Determined from test section repeatability and uniformity during tunnel calibration
RE	0.42			0.45		1.30		

[a]Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD 755356), February 1973, Ref. 6.

VB-16a (9-79)

TABLE 3 TEST SUMMARY

a.) SURFACE HEAT TRANSFER

MODEL CONFIG.	RN IN.	α DEG	Φ DEG	M	RE/FT $\times 10^{-6}$	RUN
7° CONE	0.0015	0	−90	8.0	2.5	2
					1.2	4
					1.0	5
	0.150				2.5	1
	0.500				3.5	3
	2.000				3.5	113, 116, 119

b.) SURFACE PRESSURE (TYPE 2 DATA)

MODEL CONFIG.	RN IN.	α DEG	Φ DEG	M	RE/FT $\times 10^{-6}$	RUN
7° CONE	0.150	0	−90	8.0	2.5	72, 73
7° CONE	2.000	0	−90	8.0	3.5	130, 131

TABLE 3 CONTINUED

C.) HOT-WIRE QUALITATIVE SURVEY MATRIX (TYPE 3 DATA)

RN	RE/FT $\times 10^{-6}$	X, STATION												
		10	14	15	17	20	25	27	30	33	34	35	36	37
.0015	1.0	RUN 51	46		42	34		26	21	16	15	12	11	8
0.150	2.5	96	88		84	79	67	64	60	57				54
0.500	3.5	140		141	142	139*	138					134		
2.000	3.5											129, 132		

$\alpha = 0.0$ DEG $\phi = -90$ DEG $M = 8.0$

d.) MEAN FLOW BOUNDARY LAYER SURVEY MATRIX (TYPE 4 DATA)

RN	RE/FT $\times 10^{-6}$	X, STATION						
		10	15	16	20	25	30	35
0.0015	1.0	RUN 112	111		110	109	108	107
0.150	2.5	106	105		76, 104	103	75, 102	74, 101
2.00	3.5			124, 125		123		122

$\alpha = 0.0$ DEG. $\phi = -90$ DEG $M = 8.0$

TABLE 3 CONTINUED

e) HOT-WIRE QUANTITATIVE RUN MATRIX (TYPE 9 DATA)

RN IN.	RE/FT $\times 10^{-6}$	X, STATION 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	[illegible]
0.0015	1.0	RUN 50	49	48	47	45	44	43	41	36 40	35	33	32	31	30	29	28	27	25	24	22 23	20	19	18	17	14	13	10	9	38 39
0.15	2.5	95	94	93	97	87	86	85	83	82	81	78	71	70	69	68	66	65	63	62	61	59	58		56		55		53	98,99 100,115 117 118
0.50	3.5																										135 136			
2.00	3.5																										120,121 127,128			

$\alpha = 0 \quad \phi = -90 \quad M = 8.0$

TABLE 3 CONCLUDED.

F.) HOT-WIRE ANEMOMETER* AND TOTAL TEMPERATURE PROBE CALIBRATION IN FREE-STREAM (TYPE 6 DATA)

RUN	PT (RANGE) PSI	RE (RANGE) PER IN. X10^-5	HOT-WIRE NO.
6	202 - 355	0.75-1.3	6
7	150 - 352	0.56 - 1.3	7
37	152 - 352	0.57 - 1.3	7
52	352 - 579	1.3 - 2.1	8
77	349 - 577	1.3 - 2.1	14
80	300 - 582	1.1 - 2.1	15
92	300 - 577	1.1 - 2.1	17
114	400 - 804	1.4 - 2.9	3
126	399 - 808	1.4 - 2.9	2
133	398 - 806	1.4 - 2.9	1
137	399 - 807	1.4 - 2.9	16

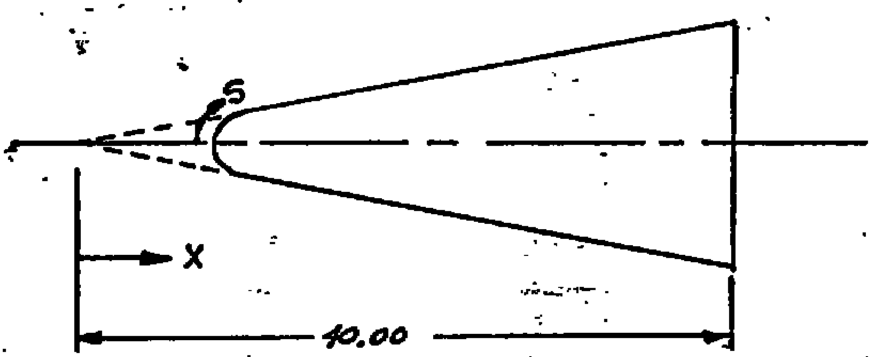
* TYPE 6 HOT-WIRE ANEMOMETER DATA WERE RECORDED ON MAGNETIC TAPE FOR FUTURE ANALYSIS. NONE OF THESE RESULTS ARE GIVEN IN THIS REPORT.

G.) HOT-WIRE IDENTIFICATION

HOT-WIRE NO.	RUN NO.
6	6
7	7-51
8	52-71
14	77-79
15	80-91
17	92-100
3	114-121
2	126-128
1	133-136
16	137-142

TABLE 4 SURVEY STATIONS

	S, IN.			
X (STA)	#1 (RN=.0015)	#2(RN=.15)	#3(RN=.50)	#4(RN=2.00)
10	10.065	9.075	6.725	
14	14.095	13.105		
15	15.102	14.112	11.762	
16				2.730
17	17.117	16.127	13.777	
19			15.950	
20	20.139	19.150		
25	25.177	24.187	21.837	11.797
27	27.192	26.202		
30	30.215	29.225		
33	33.237	32.247		
34	34.245			
35	35.252	34.262	31.912	21.872
36	36.260			
37	37.267	36.277		



APPENDIX III

SAMPLE DATA

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE

DATE COMPUTED 8-NOV-79
TIME COMPUTED 08:37:33
DATE RECORDED 21-SEP-79
TIME RECORDED 20:54:23
PROJECT NUMBER V41B-B2

AFOSR/AFFDL TRANSITION ON SLENDER CONES

RUN 1
M = 7.99

ALPHA SECTOR= 0.02 DEG.
MODEL ROLL =90.00 DEG.

CONFIGURATION
7-DEG CONE

NOSE RADIUS,IN
0.1500

TRIP
NONE

DATA TYPE: SURFACE HEAT TRANSFER

SREF = 39.300,IN

GAGE NO	S	S/SREF	THETA	QDOT	TW	H(TT)	ST(TT)
1	37.796	0.962	180.	1.143	539.896	1.403E-03	8.846E-04
3	36.596	0.931	180.	0.949	539.072	1.161E-03	7.334E-04
4	35.796	0.908	180.	0.748	536.602	9.166E-04	5.780E-04
7	32.296	0.822	180.	0.573	538.721	7.074E-04	4.430E-04
9	30.236	0.769	180.	0.442	538.294	5.409E-04	3.411E-04
10	28.936	0.736	180.	0.423	538.311	5.180E-04	3.266E-04
11	28.236	0.718	180.	0.396	538.217	4.847E-04	3.056E-04
13	26.236	0.668	180.	0.448	538.383	5.486E-04	3.460E-04
14	DELETE						
15	DELETE						
16	DELETE						
17	DELETE						
18	DELETE						
20	19.146	0.487	180.	0.494	538.691	6.058E-04	3.820E-04
22	17.146	0.436	180.	0.521	538.892	6.391E-04	4.030E-04
24	15.146	0.385	180.	0.533	539.159	6.531E-04	4.118E-04
26	13.146	0.335	180.	0.537	538.718	6.579E-04	4.148E-04
27	12.146	0.309	180.	0.613	538.969	7.517E-04	4.740E-04
28	11.146	0.284	180.	0.638	539.298	7.825E-04	4.934E-04
30	9.146	0.233	180.	0.700	539.933	8.593E-04	5.419E-04
31	8.146	0.207	180.	0.747	539.981	9.155E-04	5.779E-04

RUN 1
DEW PT. = -44.00DEG F
C.R. = 16.0 IN

PT = 570.53
TT =1354.7 DEG R
P = 5.974E-02 PSIA
RE = 2.490E+06 PER FT
MU = 7.918E-08 LBF-SEC/FT2

V = 3885.3 FT/SEC
Q = 2.670 PSIA
T = 98.4 DEGR
PT2 = 4.94 PSIA
RHO = 1.639E-03 LBM/FT3

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON SLENDER CONES

DATE COMPUTED 28-NOV-79
TIME COMPUTED 13:42:40
DATE RECORDED 24-SEP-79
TIME RECORDED 5:19:19
PROJECT NUMBER V41B-B2

RUN NUMBER 72 PAGE 5

DATA TYPE 2
MODEL SURFACE MEASUREMENTS

BLUNT 7-DEG CONE (RN = 0.10 IN.)

LOOP 6

TAP	S (IN)	THETA (DEG)	PW (PSIA)	PW/P
1	38.797	0	0.1542	2.5673
2	37.797	0	0.1566	2.6059
3	37.297	0	0.1562	2.5994
4	35.297	0	0.1563	2.6015
5	33.297	0	0.1607	2.6742
6	31.237	0	0.1600	2.6622
7	29.237	0	0.1613	2.6852
8	27.237	0	0.1595	2.6548
9	25.237	0	0.1608	2.6756
10	23.237	0	0.1614	2.6866
11	21.237	0	0.1595	2.6548
12	19.147	0	0.1572	2.6413
13	16.147	0	0.1606	2.6979
14	14.147	0	0.1591	2.6736
15	12.147	0	0.1574	2.6447
16	10.147	0	0.1589	2.6695
17	8.147	0	0.1569	2.6370
18	7.147	0	0.1568	2.6341
19	10.147	270	0.1569	2.6370
20	10.147	180	0.1594	2.6780
21	29.237	270	0.1622	2.6990
22	29.237	180	0.1627	2.7080
23	38.797	270	0.1558	2.5936
24	38.797	180	0.1571	2.6155

T/C	S (IN)	THETA (DEG)	TW (DEG F)	TW/TT
1	37.796	180	892.1	0.661
2	37.296	180	902.8	0.669
3	36.596	180	917.8	0.680
4	35.796	180	945.7	0.701
5	34.796	180	967.2	0.717
6	33.296	180	989.7	0.733
7	32.296	180	1010.1	0.748
8	31.736	180	1011.4	0.749
9	30.236	180	1012.6	0.750
10	28.936	180	1011.8	0.750
11	28.236	180	1013.6	0.751
12	27.236	180	1014.0	0.751
13	26.236	180	1014.4	0.752
14	25.236	180	1018.7	0.755
15	24.236	180	1023.0	0.758
16	23.236	180	1027.3	0.761
17	22.236	180	1031.4	0.764
18	21.236	180	1035.9	0.768
19	20.146	180	1040.6	0.771
20	19.146	180	1044.9	0.774
21	18.146	180	1049.8	0.778
22	17.146	180	1054.7	0.781
23	16.146	180	1058.5	0.784
24	15.146	180	1062.3	0.787
25	14.146	180	1068.1	0.791
26	13.146	180	1073.8	0.796
27	12.146	180	1076.2	0.797
28	11.146	180	1079.0	0.799
29	9.846	180	1084.2	0.803
30	9.146	180	1087.0	0.805
31	8.146	180	1092.0	0.809
32	7.146	180	1097.0	0.813

PHI = -90.0 DEG
M = 7.9980
ALPHA = -0.0 DEG

PT = 876.3 PSIA
TT =1349.7 DEG R
P = 0.0596 PSIA
RE = 0.2092+06 PER IN
PT2 = 4.919 PSIA

TDRK = 535.7 DEG R

THE VALUES OF THE FOLLOWING THERMOCOUPLES HAVE BEEN INTERPOLATED 1 2 4 5 6 8 12 14 15 16 17 18 19 21 23 25 29 32

RUN NUMBER 72

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON SLENDER CONES

DATE COMPUTED 28-NOV-79
TIME COMPUTED 13:42:07
DATE RECORDED 24-SEP-79
TIME RECORDED 3:36:28
PROJECT NUMBER V41B-B2

RUN NUMBER 67 PAGE 1

DATA TYPE 3
FLOW FIELD SURVEY
PROBE KAT (HOT WIRE ANEMOMETER AND TOTAL TEMP. PROBE)

BLUNT 7-DEG CONE (RN = 0.15 IN.)
XM 35.00

LOOP	PT (PSIA)	TT (DEG R)	PT2 (PSIA)	P (PSIA)	PWL (PSIA)	TWL (DEG R)	ZT (IN)	TTTU (DEG R)	ZA (IN)	ERMS
1	579.11	1353.7	4.943	0.060	0.160	1078.9	0.0145	1120.4	0.0145	1.3300E+02
2	578.71	1353.7	4.940	0.060	0.160	1078.9	0.0249	1131.4	0.0249	1.3300E+02
3	579.51	1353.7	4.947	0.060	0.160	1078.9	0.0347	1136.4	0.0347	1.3300E+02
4	578.81	1353.7	4.941	0.060	0.160	1078.9	0.0451	1137.1	0.0451	1.3200E+02
5	578.61	1353.7	4.939	0.060	0.160	1078.9	0.0549	1130.3	0.0549	1.3300E+02
6	579.71	1353.7	4.949	0.060	0.160	1078.9	0.0538	1133.9	0.0538	1.3200E+02
7	579.11	1353.7	4.945	0.060	0.160	1078.9	0.0642	1123.3	0.0642	1.3400E+02
8	579.51	1353.7	4.947	0.060	0.160	1078.9	0.0746	1136.6	0.0746	1.4100E+02
9	579.11	1353.7	4.943	0.060	0.160	1078.9	0.0847	1165.3	0.0847	1.4600E+02
10	579.01	1353.7	4.942	0.060	0.160	1078.9	0.0938	1201.6	0.0938	1.6600E+02
11	579.21	1353.7	4.944	0.060	0.160	1078.9	0.1039	1225.6	0.1039	1.8100E+02
12	579.51	1353.7	4.947	0.060	0.160	1078.9	0.1144	1236.0	0.1144	3.3800E+02
13	579.01	1353.7	4.942	0.069	0.160	1078.9	0.1241	1230.0	0.1241	3.5700E+02
14	578.71	1353.7	4.940	0.060	0.160	1078.9	0.1341	1226.0	0.1341	2.0300E+02
15	579.31	1353.7	4.945	0.060	0.160	1078.9	0.1445	1225.1	0.1445	1.6800E+02
16	579.51	1353.7	4.947	0.060	0.160	1078.9	0.1533	1224.4	0.1533	1.5700E+02
17	578.71	1353.7	4.940	0.060	0.160	1078.9	0.1634	1224.2	0.1634	1.5200E+02
18	579.61	1353.7	4.947	0.060	0.160	1078.9	0.1734	1224.0	0.1734	1.5100E+02
19	579.21	1352.7	4.944	0.060	0.160	1078.1	0.1836	1223.6	0.1836	1.5100E+02
20	578.91	1353.7	4.941	0.060	0.160	1078.9	0.1929	1223.7	0.1929	1.5000E+02
21	579.11	1353.7	4.943	0.060	0.160	1078.9	0.2029	1223.3	0.2029	1.4900E+02
22	579.61	1353.7	4.947	0.060	0.160	1078.9	0.2133	1223.5	0.2133	1.4800E+02
23	579.01	1352.7	4.942	0.060	0.160	1078.1	0.2235	1223.6	0.2235	1.4800E+02
24	579.71	1352.7	4.948	0.060	0.160	1078.1	0.2333	1223.7	0.2333	1.4900E+02
25	578.91	1352.7	4.941	0.060	0.160	1078.1	0.2427	1223.7	0.2427	1.4800E+02
26	579.61	1353.7	4.947	0.060	0.160	1078.9	0.2527	1223.7	0.2527	1.4700E+02
27	579.61	1353.7	4.947	0.060	0.160	1078.9	0.2632	1223.4	0.2632	1.4700E+02
28	579.41	1352.7	4.946	0.060	0.160	1078.1	0.2726	1223.6	0.2726	1.4700E+02
29	578.91	1352.7	4.941	0.060	0.160	1078.1	0.2838	1223.7	0.2838	1.4800E+02
30	579.41	1353.7	4.946	0.060	0.160	1078.9	0.2929	1220.2	0.2929	1.4600E+02
31	579.21	1353.7	4.944	0.060	0.160	1078.9	0.3024	1223.6	0.3024	1.4600E+02
32	579.31	1352.7	4.945	0.060	0.160	1078.1	0.3131	1223.6	0.3131	1.4600E+02

MEAN VALUES

PHI = -90.0 DEG
M = 7.99
ALPHA = 0.0 DEG

PT = 579.2 PSIA
TT = 1353.5 DEG R
PT2 = 4.944 PSIA
RE = 2.088E+05 PER IN
MU = 7.911E-08 LBF-SEC/FT2
RHO = 1.642E-03 LBM/FT3

P = 0.0598 PSIA
PWL = 0.160 PSIA
TWL = 1078.7 DEG R
V = 3883.5 FT/SEC
Q = 2.673 PSIA
T = 98.3 DEG R

RUN NUMBER 67

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON SLENDER CONES

DATE COMPUTED 3-DEC-79
TIME COMPUTED 21:08:39
DATE RECORDED 24-SEP-79
TIME RECORDED 6:51:20
PROJECT NUMBER V41B-B2

RUN NUMBER 74 PAGE 1

DATA TYPE 4
FLOW FIELD SURVEY
PROBE FXT

BLUNT 7-DEG CONE (RN = 0.15 IN.)
X= 15.01

LOOP	PT (PSIA)	TT (DEG F)	PT2 (PSIA)	P (PSIA)	ZP (IN)	PP (PSIA)	PWL (PSIA)	TWL (DEG R)	ST (IN)	TTTU (DEG R)	ZA (IN)	TTA (DEG R)	MA	LRETA
1	569.11	1353.7	4.952	0.060	0.0490	0.261	0.159	1006.1	0.0088	1090.8	0.0088	1027.7	1.81E-01	4.898E+02
2	579.81	1353.7	4.949	0.060	0.0587	0.303	0.159	1006.1	0.0185	1082.2	0.0185	1050.3	3.69E-01	9.968E+02
3	579.81	1353.7	4.949	0.060	0.0690	0.379	0.159	1006.1	0.0288	1082.9	0.0288	1073.1	5.54E-01	1.499E+03
4	579.51	1353.7	4.947	0.060	0.0787	0.487	0.159	1006.1	0.0385	1085.6	0.0385	1093.4	7.14E-01	1.939E+03
5	579.41	1353.7	4.946	0.060	0.0891	0.716	0.159	1006.1	0.0489	1094.2	0.0489	1113.9	8.72E-01	2.373E+03
6	579.31	1353.7	4.945	0.060	0.0990	1.050	0.159	1006.1	0.0588	1106.8	0.0588	1132.3	1.01E+00	2.751E+03
7	579.61	1354.7	4.947	0.060	0.1084	1.589	0.158	1006.8	0.0682	1122.3	0.0682	1155.5	1.18E+00	3.232E+03
8	579.61	1354.7	4.947	0.060	0.1189	2.546	0.159	1006.8	0.0787	1145.0	0.0787	1189.2	1.41E+00	3.901E+03
9	579.81	1354.7	4.949	0.060	0.1298	4.243	0.159	1006.8	0.0896	1172.3	0.0896	1234.7	1.78E+00	5.142E+03
10	580.21	1354.7	4.953	0.060	0.1383	5.687	0.159	1006.8	0.0981	1189.3	0.0981	1265.9	2.14E+00	6.465E+03
11	580.01	1354.7	4.951	0.060	0.1497	7.734	0.159	1006.8	0.1095	1211.3	0.1095	1304.1	2.79E+00	9.418E+03
12	580.82	1354.7	4.958	0.060	0.1591	8.818	0.159	1006.8	0.1189	1226.5	0.1189	1338.6	3.48E+00	1.320E+04
13	580.01	1354.7	4.951	0.060	0.1692	9.192	0.159	1006.8	0.1290	1235.1	0.1290	1356.3	4.45E+00	2.005E+04
14	580.62	1354.7	4.956	0.060	0.1791	9.224	0.159	1006.8	0.1389	1234.6	0.1389	1356.8	5.29E+00	2.747E+04
15	580.92	1354.7	4.959	0.060	0.1888	9.203	0.159	1006.8	0.1486	1230.5	0.1486	1350.1	6.05E+00	3.556E+04
16	580.62	1354.7	4.956	0.060	0.1999	9.127	0.159	1006.8	0.1597	1227.1	0.1597	1343.9	6.55E+00	4.158E+04
17	580.62	1354.7	4.956	0.060	0.2090	9.077	0.159	1006.8	0.1687	1226.2	0.1687	1342.2	6.68E+00	4.306E+04
18	580.42	1354.7	4.954	0.060	0.2192	9.039	0.159	1006.8	0.1789	1225.6	0.1789	1341.5	6.69E+00	4.330E+04
19	580.62	1354.7	4.956	0.060	0.2287	9.023	0.159	1006.8	0.1884	1225.5	0.1884	1341.4	6.68E+00	4.321E+04
20	581.02	1354.7	4.959	0.060	0.2397	9.006	0.159	1006.8	0.1994	1225.4	0.1994	1341.4	6.65E+00	4.288E+04
21	581.32	1354.7	4.962	0.060	0.2498	9.009	0.159	1006.8	0.2095	1224.8	0.2095	1340.8	6.63E+00	4.265E+04
22	581.12	1354.7	4.960	0.060	0.2591	9.000	0.159	1006.8	0.2188	1224.9	0.2188	1341.0	6.62E+00	4.249E+04
23	580.62	1354.7	4.956	0.060	0.2701	9.001	0.159	1006.8	0.2298	1225.1	0.2298	1341.3	6.61E+00	4.239E+04
24	579.61	1354.7	4.947	0.060	0.2786	8.995	0.159	1006.8	0.2383	1225.3	0.2383	1341.5	6.61E+00	4.237E+04
25	579.01	1354.7	4.942	0.060	0.2892	8.991	0.158	1006.8	0.2489	1225.1	0.2489	1341.3	6.61E+00	4.234E+04
26	579.11	1354.7	4.948	0.060	0.3004	8.997	0.159	1006.8	0.2601	1225.3	0.2601	1341.5	6.60E+00	4.229E+04
27	579.01	1354.7	4.947	0.060	0.3094	8.989	0.158	1006.8	0.2691	1224.9	0.2691	1341.2	6.61E+00	4.231E+04
28	578.71	1354.7	4.940	0.060	0.3199	8.994	0.158	1006.8	0.2796	1224.8	0.2796	1341.0	6.61E+00	4.228E+04
29	578.81	1354.7	4.941	0.060	0.3295	9.001	0.158	1006.8	0.2892	1224.8	0.2892	1341.0	6.61E+00	4.226E+04
30	578.41	1354.7	4.937	0.060	0.3399	9.002	0.158	1006.8	0.2996	1224.9	0.2996	1341.1	6.61E+00	4.229E+04
31	578.11	1354.7	4.940	0.060	0.3498	9.004	0.158	1006.8	0.3095	1224.8	0.3095	1341.0	6.61E+00	4.225E+04

PHI = -90.0 DEG
M = 7.90
ALPHA = 0.0 DEG

MEAN VALUES

PT = 579.9 PSIA
TT = 1354.5 DEG R
PT2 = 4.950 PSIA
RE = 2.848E+05 PER IN
MU = 7.917E-08 LBF-SEC/FT2
RHO = 1.643E-03 LBM/FT3

P = 0.0599 PSIA
PWL = 0.159 PSIA
TWL = 1006.7 DEG R
V = 3885.0 FT/SEC
Q = 2.676 PSIA
T = 98.4 DEG R

RUN NUMBER 74

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON BLUNTED CONES

DATE COMPUTED 3-DEC-79
TIME COMPUTED 21:09:39
DATE RECORDED 24-SEP-79
TIME RECORDED 6:51:20
PROJECT NUMBER V41B-B2

RUN NUMBER 74 PAGE 2

DATA TYPE 4
FLOW FIELD SURVEY
PROBE EXT

BLUNT 7-DEG CONE (RN = 0.15 IN.)
X= 35.01

LOOP	ZP (IN)	PP/PPE	ML	ML/ME	TTLU (DEG R)	TTE (DEG R)	TTL/TTE	TL (DEG R)	UL (FT/SEC)	UL/UE	LPE	LPET
1	0.0490	0.028	8.74E-01	0.131	1044.3	1114.1	0.830	966.6	1.332E+03	0.350	2.611E+03	2.377E+03
2	0.0587	0.033	1.01E+00	0.151	1106.6	1132.1	0.843	941.0	1.515E+03	0.399	3.106E+03	2.748E+03
3	0.0690	0.041	1.19E+00	0.179	1123.8	1157.8	0.863	901.0	1.756E+03	0.461	3.872E+03	3.279E+03
4	0.0787	0.053	1.41E+00	0.211	1145.0	1189.2	0.886	857.1	2.011E+03	0.528	4.871E+03	3.903E+03
5	0.0891	0.078	1.77E+00	0.264	1171.3	1232.3	0.918	758.8	2.185E+03	0.626	7.029E+03	5.076E+03
6	0.0990	0.114	2.18E+00	0.327	1191.1	1269.4	0.946	649.8	2.729E+03	0.717	1.050E+04	6.654E+03
7	0.1054	0.173	2.77E+00	0.408	1209.4	1305.4	0.973	525.8	3.061E+03	0.804	1.704E+04	9.064E+03
8	0.1189	0.277	3.48E+00	0.521	1226.5	1338.7	0.997	391.3	3.374E+03	0.886	3.209E+04	1.322E+04
9	0.1298	0.443	4.52E+00	0.677	1215.4	1357.0	1.011	264.5	3.620E+03	0.951	7.095E+04	2.065E+04
10	0.1383	0.619	5.24E+00	0.784	1234.7	1357.0	1.011	209.0	3.714E+03	0.975	1.173E+05	2.703E+04
11	0.1487	0.841	6.12E+00	0.917	1230.1	1349.4	1.005	158.8	3.782E+03	0.993	2.068E+05	3.636E+04
12	0.1591	0.959	6.54E+00	0.979	1227.2	1344.1	1.001	140.8	3.802E+03	0.998	2.649E+05	4.138E+04
13	0.1692	1.000	6.68E+00	1.000	1226.2	1342.2	1.000	135.2	3.808E+03	1.000	2.871E+05	4.313E+04
14	0.1791	1.003	6.69E+00	1.001	1225.6	1341.5	0.999	134.9	3.808E+03	1.000	2.890E+05	4.330E+04
15	0.1888	1.001	6.68E+00	1.000	1225.5	1341.4	0.999	135.2	3.807E+03	1.000	2.876E+05	4.321E+04
16	0.1999	0.991	6.65E+00	0.996	1225.4	1341.4	0.999	136.1	3.806E+03	0.999	2.833E+05	4.287E+04
17	0.2090	0.987	6.64E+00	0.993	1224.8	1340.8	0.999	136.8	3.804E+03	0.999	2.806E+05	4.266E+04
18	0.2192	0.981	6.62E+00	0.991	1224.9	1341.0	0.999	137.3	3.803E+03	0.999	2.785E+05	4.248E+04
19	0.2287	0.982	6.61E+00	0.990	1225.1	1341.3	0.999	137.6	3.803E+03	0.999	2.774E+05	4.240E+04
20	0.2397	0.980	6.61E+00	0.989	1225.3	1341.5	1.000	137.9	3.803E+03	0.999	2.767E+05	4.232E+04
21	0.2496	0.980	6.61E+00	0.989	1225.1	1341.3	0.999	137.9	3.803E+03	0.999	2.763E+05	4.234E+04
22	0.2591	0.979	6.60E+00	0.988	1225.3	1341.6	1.000	138.0	3.803E+03	0.999	2.758E+05	4.229E+04
23	0.2691	0.979	6.61E+00	0.989	1224.9	1341.1	0.999	137.8	3.802E+03	0.998	2.767E+05	4.231E+04
24	0.2786	0.979	6.61E+00	0.989	1224.8	1341.0	0.999	137.7	3.803E+03	0.999	2.763E+05	4.228E+04
25	0.2892	0.978	6.61E+00	0.990	1224.8	1341.0	0.999	137.6	3.803E+03	0.999	2.763E+05	4.226E+04
26	0.3003	0.979	6.61E+00	0.990	1224.9	1341.1	0.999	137.7	3.801E+03	0.999	2.763E+05	4.229E+04
27	0.3098	0.978	6.61E+00	0.990	1224.8	1341.0	0.999	137.7	3.801E+03	0.999	2.762E+05	4.225E+04
28	0.3199	0.978	6.61E+00	0.990	1224.5	1340.7	0.999	137.5	3.802E+03	0.998	2.767E+05	4.228E+04
29	0.3295	0.979	6.62E+00	0.991	1224.1	1340.3	0.999	137.4	3.802E+03	0.998	2.772E+05	4.233E+04
30	0.3399	0.979	6.62E+00	0.991	1223.5	1339.6	0.998	137.2	3.801E+03	0.998	2.776E+05	4.236E+04
31	0.3496	0.980	6.62E+00	0.991	1222.7	1338.7	0.997	137.1	3.800E+03	0.998	2.779E+05	4.240E+04

MEAN VALUES

PHI = -90.0 DEG
M = 7.94
ALPHA = 0.0 DEG

PT = 579.9 PSIA
TT =1354.5 DEG R
P = 0.0589 PSIA
T = 98.4 DEG R

TWL/TTE = 0.7500
PWL = 0.159 PSIA
TWL =1006.7 DEG R

EDGE VALUES

PPE = 9.192E+00 PSIA
ME = 6.680E+00
TTE = 1.342E+03 DEG R
UE = 0.381E+04 FT/SEC

RUN NUMBER 74

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON BLUNTED CONES

DATE COMPUTED 3-DEC-79
TIME COMPUTED 21:08:40
DATE RECORDED 24-SEP-79
TIME RECORDED 6:51:20
PROJECT NUMBER V41B-02

RUN NUMBER 74 PAGE 3

DATA TYPE 4
FLOW FIELD SURVEY
PROBE FXT
MODEL SURFACE MEASUREMENTS

BLUNT 7-DEG CONE (RN = 0.15 IN.)
X= 35.01

TAP	S (IN)	THETA (DEG)	PW (PSIA)	SD PW (PSI)	PW/P
4	35.237	0	0.1561	0.0002	2.6063
5	33.237	0	0.1604	0.0002	2.6788
6	31.237	0	0.1602	0.0004	2.6759
7	29.237	0	0.1604	0.0002	2.6787
8	27.237	0	0.1589	0.0002	2.6537
9	25.237	0	0.1605	0.0002	2.6799
10	23.237	0	0.1610	0.0002	2.6880
11	21.237	0	0.1591	0.0002	2.6561
21	29.237	270	0.1617	0.0002	2.6999
22	29.237	180	0.1624	0.0002	2.7115

T/C	S (IN)	THETA (DEG)	TW (DEG R)	SD TW (DEG R)	TW/TT
3	36.596	180	1001.9	0.64	0.740
4	35.296	180	1002.6	0.57	0.740
5	34.296	180	1003.6	0.46	0.741
6	33.296	180	1005.3	0.28	0.742
7	32.296	180	1006.6	0.14	0.743
8	31.236	180	1008.0	0.09	0.744
9	30.236	180	1009.3	0.20	0.745
10	29.936	180	1008.8	0.18	0.745
11	28.236	180	1010.8	0.19	0.746
12	27.236	180	1012.0	0.17	0.747
13	26.236	180	1012.7	0.19	0.748
14	25.236	180	1017.3	0.16	0.751
15	24.236	180	1021.9	0.14	0.754
16	23.236	180	1026.5	0.11	0.758
17	22.236	180	1031.1	0.10	0.761
18	21.236	180	1035.7	0.09	0.765
19	20.146	180	1040.3	0.09	0.768
20	19.146	180	1044.9	0.10	0.771
21	18.146	180	1050.5	0.15	0.776
22	17.146	180	1055.7	0.32	0.779
23	16.146	180	1060.1	0.29	0.783
24	15.146	180	1064.4	0.34	0.786
25	14.146	180	1069.3	0.22	0.789
26	13.146	180	1074.2	0.27	0.793
27	12.146	180	1077.2	0.12	0.795
28	11.146	180	1080.4	0.21	0.798
29	9.846	180	1084.3	0.15	0.801
30	9.146	180	1088.3	0.16	0.803
31	8.146	180	1093.3	0.42	0.807
32	7.146	180	1096.0	0.62	0.809

MEAN VALUES

PHI = -90.0 DEG
M = 7.90
ALPHA = 0.0 DEG

PT = 579.9 PSIA
TT =1354.5 DEG R
P = 0.0599 PSIA

TOPK = 543.7 DEG R
T = 98.4 DEG R

THE VALUES OF THE FOLLOWING THERMOCOUPLES HAVE BEEN INTERPOLATED 3 4 5 6 8 12 14 15 16 17 18 19 21 23 28 29 32

RUN NUMBER 74

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON SLENDER CONES

DATE COMPUTED 3-DEC-79
TIME COMPUTED 21:08:40
DATE RECORDED 24-SEP-79
TIME RECORDED 6:51:20
PROJECT NUMBER V41B-B2

DATA TYPE 4
FLOW FIELD SURVEY
PROBE PAT

BLUNT 7-DEG CONE (RN = 0.15 IN.)
XO 35.01

INTEGRAL EVALUATION

LOOP	ZP/DEL	PP/PPD	ML/MD	TTL/TTD	TL/TD	RHOL/RHOD	UL/UD	MUTL/MUTD	LRE/LRED	DITTL/DITTD	LRET/LRETD
1	3.204E-01	3.196E-02	1.388E-01	8.769E-01	6.434E+00	1.563E-01	3.511E-01	4.843E+00	1.144E-02	3.133E-01	6.199E-02
2	3.839E-01	3.714E-02	1.600E-01	8.402E-01	6.264E+00	1.604E-01	3.995E-01	4.756E+00	1.360E-02	3.658E-01	7.167E-02
3	4.512E-01	4.641E-02	1.896E-01	8.591E-01	5.998E+00	1.676E-01	4.631E-01	4.618E+00	1.696E-02	4.409E-01	8.551E-02
4	5.147E-01	5.961E-02	2.233E-01	8.826E-01	5.672E+00	1.771E-01	5.306E-01	4.445E+00	2.134E-02	5.331E-01	1.018E-01
5	5.827E-01	8.768E-02	2.805E-01	9.146E-01	5.051E+00	1.998E-01	6.289E-01	4.099E+00	3.079E-02	6.601E-01	1.324E-01
6	6.474E-01	1.286E-01	3.468E-01	9.421E-01	4.325E+00	2.312E-01	7.194E-01	3.666E+00	4.599E-02	7.699E-01	1.735E-01
7	7.089E-01	1.946E-01	4.374E-01	9.688E-01	3.500E+00	2.870E-01	8.069E-01	3.135E+00	7.480E-02	8.746E-01	2.364E-01
8	7.775E-01	3.118E-01	5.575E-01	9.935E-01	2.605E+00	3.857E-01	8.895E-01	2.464E+00	1.405E-01	9.738E-01	3.446E-01
9	8.498E-01	5.209E-01	7.184E-01	1.007E+00	1.774E+00	5.666E-01	9.544E-01	1.756E+00	3.108E-01	1.028E+00	5.385E-01
10	9.044E-01	6.554E-01	8.323E-01	1.007E+00	1.391E+00	7.229E-01	9.797E-01	1.391E+00	5.136E-01	1.028E+00	7.050E-01
11	9.796E-01	9.470E-01	9.724E-01	1.001E+00	1.057E+00	9.512E-01	9.972E-01	1.057E+00	9.059E-01	1.006E+00	9.481E-01
12	1.041E+00	1.080E+00	1.038E+00	9.975E-01	9.370E-01	1.074E+00	1.003E+00	9.370E-01	1.160E+00	9.899E-01	1.079E+00
13	1.106E+00	1.126E+00	1.061E+00	9.961E-01	9.001E-01	1.117E+00	1.004E+00	9.001E-01	1.256E+00	9.843E-01	1.125E+00
14	1.171E+00	1.129E+00	1.062E+00	9.956E-01	8.976E-01	1.121E+00	1.004E+00	8.976E-01	1.266E+00	9.821E-01	1.129E+00
15	1.235E+00	1.127E+00	1.061E+00	9.955E-01	8.999E-01	1.119E+00	1.004E+00	8.999E-01	1.260E+00	9.819E-01	1.127E+00
16	1.307E+00	1.118E+00	1.057E+00	9.955E-01	9.062E-01	1.111E+00	1.003E+00	9.062E-01	1.241E+00	9.818E-01	1.118E+00
17	1.367E+00	1.111E+00	1.054E+00	9.951E-01	9.104E-01	1.105E+00	1.003E+00	9.104E-01	1.229E+00	9.802E-01	1.112E+00
18	1.431E+00	1.107E+00	1.052E+00	9.957E-01	9.136E-01	1.101E+00	1.003E+00	9.136E-01	1.220E+00	9.807E-01	1.106E+00
19	1.496E+00	1.105E+00	1.050E+00	9.954E-01	9.156E-01	1.099E+00	1.003E+00	9.156E-01	1.215E+00	9.816E-01	1.106E+00
20	1.568E+00	1.103E+00	1.049E+00	9.956E-01	9.179E-01	1.097E+00	1.003E+00	9.179E-01	1.210E+00	9.823E-01	1.104E+00
21	1.634E+00	1.103E+00	1.049E+00	9.955E-01	9.179E-01	1.098E+00	1.003E+00	9.179E-01	1.210E+00	9.817E-01	1.104E+00
22	1.694E+00	1.102E+00	1.049E+00	9.956E-01	9.186E-01	1.096E+00	1.003E+00	9.186E-01	1.208E+00	9.824E-01	1.103E+00
23	1.766E+00	1.102E+00	1.049E+00	9.953E-01	9.175E-01	1.097E+00	1.003E+00	9.175E-01	1.210E+00	9.811E-01	1.103E+00
24	1.822E+00	1.101E+00	1.050E+00	9.952E-01	9.166E-01	1.096E+00	1.003E+00	9.166E-01	1.210E+00	9.806E-01	1.103E+00
25	1.891E+00	1.101E+00	1.050E+00	9.952E-01	9.161E-01	1.096E+00	1.003E+00	9.161E-01	1.210E+00	9.808E-01	1.102E+00
26	1.964E+00	1.102E+00	1.050E+00	9.953E-01	9.166E-01	1.096E+00	1.003E+00	9.166E-01	1.210E+00	9.810E-01	1.103E+00
27	2.023E+00	1.101E+00	1.050E+00	9.952E-01	9.163E-01	1.095E+00	1.003E+00	9.163E-01	1.210E+00	9.809E-01	1.102E+00
28	2.092E+00	1.101E+00	1.051E+00	9.950E-01	9.152E-01	1.096E+00	1.003E+00	9.152E-01	1.212E+00	9.800E-01	1.103E+00
29	2.155E+00	1.102E+00	1.051E+00	9.947E-01	9.143E-01	1.097E+00	1.002E+00	9.143E-01	1.214E+00	9.786E-01	1.104E+00
30	2.221E+00	1.102E+00	1.051E+00	9.942E-01	9.132E-01	1.098E+00	1.002E+00	9.132E-01	1.216E+00	9.765E-01	1.105E+00
31	2.288E+00	1.103E+00	1.051E+00	9.935E-01	9.129E-01	1.099E+00	1.002E+00	9.129E-01	1.217E+00	9.740E-01	1.106E+00

PHI = -90.0 DEG
M = 7.99
ALPHA = 0.0 DEG

DEL = 1.529E-01 IN
DEL* = 1.193E-01 IN
DEL** = 4.620E-03 IN

LPED = 2.283E+05 PER IN

VALUES AT DELTA

PPD = 8.166E+00 PSIA
MD = 6.296E+00
TD = 1.502E+02 DEG R
TTD = 1.347E+03 DEG R
UD = 3.793E+03 FT/SEC

RHOD = 2.838E-03 LBM/FT3
RHOUD = 1.076E+01 LBM/SEC-FT2
MUTD = 1.209E-07 LBF-SEC/FT2
DITTD = 8.695E+01 BTU/LBM
LRETD = 3.835E+04 PER IN

ARO, INC. - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION ON SLENDER CONES

DATE COMPUTED 24-SEP-79
TIME COMPUTED 01:16:13
DATE RECORDED 24-SEP-79
TIME RECORDED 0:45:33
PROJECT NUMBER V41H-B2

RUN NUMBER 52 PAGE 1

DATA TYPE 6
FREE STREAM PROBE CALIBRATION

BLUNT 7-DEG CONE (RN = 0.15 IN.)

LOOP	M	PT (PSIA)	TT (DEG R)	RE (PER IN)	RET (PER IN)	PP (PSIA)	TTTO/TT	ML	ETA
1	7.970E+00	3.520E+02	1.358E+03	1.272E+05	1.390E+04	2.928E+00	8.904E-01	8.0362E+00	8.8177E-01
2	7.970E+00	3.519E+02	1.358E+03	1.272E+05	1.389E+04	2.929E+00	8.902E-01	8.0350E+00	8.8156E-01
3	7.970E+00	4.026E+02	1.358E+03	1.454E+05	1.589E+04	3.336E+00	8.912E-01	8.0427E+00	8.8261E-01
4	7.970E+00	4.025E+02	1.358E+03	1.454E+05	1.589E+04	3.338E+00	8.910E-01	8.0412E+00	8.8239E-01
5	7.980E+00	4.534E+02	1.355E+03	1.638E+05	1.784E+04	3.748E+00	8.926E-01	8.0471E+00	8.8412E-01
6	7.980E+00	4.529E+02	1.355E+03	1.636E+05	1.782E+04	3.748E+00	8.928E-01	8.0452E+00	8.8433E-01
7	7.980E+00	5.010E+02	1.357E+03	1.806E+05	1.968E+04	4.137E+00	8.942E-01	8.0491E+00	8.8585E-01
8	7.980E+00	5.011E+02	1.357E+03	1.806E+05	1.968E+04	4.136E+00	8.943E-01	8.0499E+00	8.8605E-01
9	7.990E+00	5.789E+02	1.355E+03	2.084E+05	2.265E+04	4.764E+00	8.963E-01	8.0551E+00	8.8818E-01
10	7.990E+00	5.788E+02	1.355E+03	2.084E+05	2.264E+04	4.763E+00	8.962E-01	8.0552E+00	8.8811E-01

RUN NUMBER 52

ARO, INC - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
AFOSR/AFFDL TRANSITION

DATE COMPUTED 16-NOV-79
DATE RECORDED 24-SEP-79
TIME COMPUTED 06:32
TIME RECORDED 2: 3:52

PROJECT NO V41B-B2

RUN 55 WIRE NUMBER 8 MACH NUMBER 7.99 TIME 2 3 52

DATA TYPE 9 HOT WIRE ANEMOMETER DATA X = 35.00

NO	ZA	CURRENT	EBAR	ERMS	PT	TT	P	Q	T	RE
1	0.139	0.002	0.05	130.62	5.782E+02	1.351E+03	5.971E-02	2.668E+00	9.810E+01	2.091E+05
2	0.138	0.138	16.41	132.67	5.782E+02	1.351E+03	5.971E-02	2.668E+00	9.810E+01	2.091E+05
3	0.138	0.201	24.11	135.59	5.783E+02	1.352E+03	5.972E-02	2.669E+00	9.817E+01	2.089E+05
4	0.138	0.402	48.47	148.97	5.783E+02	1.351E+03	5.972E-02	2.669E+00	9.810E+01	2.091E+05
5	0.138	0.601	72.81	165.33	5.783E+02	1.351E+03	5.972E-02	2.669E+00	9.810E+01	2.091E+05
6	0.138	0.792	96.67	180.52	5.784E+02	1.352E+03	5.973E-02	2.669E+00	9.817E+01	2.089E+05
7	0.138	1.000	123.78	195.07	5.784E+02	1.352E+03	5.973E-02	2.669E+00	9.817E+01	2.089E+05
8	0.138	1.194	148.89	208.84	5.783E+02	1.352E+03	5.972E-02	2.669E+00	9.817E+01	2.089E+05
9	0.138	1.402	177.29	233.89	5.784E+02	1.352E+03	5.972E-02	2.669E+00	9.817E+01	2.089E+05
10	0.138	1.603	206.01	282.49	5.784E+02	1.352E+03	5.973E-02	2.669E+00	9.817E+01	2.089E+05
11	0.138	1.797	235.18	365.02	5.784E+02	1.352E+03	5.973E-02	2.669E+00	9.817E+01	2.089E+05
12	0.138	2.018	270.21	509.61	5.784E+02	1.352E+03	5.973E-02	2.669E+00	9.817E+01	2.089E+05